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CHESAPEAKE BAY NUTRIENT INPUT STUDY

Victor Guide, et al

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Annapolis, Maryland

September 1972

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Annapolis Field Office
Region III
Environmental Protection Agency

CHESAPEAKE BAY

NUTRIENT INPUT STUDY

Technical Report 47

September 1972

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PREFACE

The Chesapeake Bay, the largest tidal estuary on the Atlantic Coast, is regarded as one of the most valuable estuaries in the world and is ~~utilized~~ used extensively for fishing, recreation, navigation, and waste assimilation. This extensive utilization has resulted in an ever increasing stress on the ability of the Bay to accomodate the diverse and often conflicting demands made upon it.

To determine the magnitude, extent, and source of nutrient loadings to the Chesapeake Bay data from a water quality survey of the major tributary watersheds (the Susquehanna, the Patuxent, the Potomac, the Rappahannock, the Mattaponi, the Pamunkey, the Chickahominy, and the James) have been evaluated and are presented in this report.

TABLE OF CONTENTS

Page

PREFACE ii

LIST OF TABLES vi

LIST OF FIGURES viii

Chapter

I. INTRODUCTION I-1

- A. Purpose and Scope I-1
- B. Description of the Sampling Network I-2
- C. Authority I-4
- D. Acknowledgements I-4

II. SUMMARY AND CONCLUSIONS II-1

III. DESCRIPTION OF THE STUDY AREA III-1

- A. Chesapeake Bay III-1
- B. Tributary Watersheds III-3
  - 1. Susquehanna River Basin III-3
  - 2. Patuxent River Basin III-4
  - 3. Potomac River Basin III-6
  - 4. Rappahannock River Basin III-8
  - 5. York River Basin III-10
    - a. Mattaponi River III-11
    - b. Pamunkey River III-11
  - 6. James River Basin III-12
    - a. Chickahominy River Watershed III-13

TABLE OF CONTENTS

Chapter — Page

IV. WATER QUALITY CONDITIONS — IV-1
  A. Susquehanna River at Conowingo, Maryland — IV-2
  B. Patuxent River at Route 50 (John Hanson Highway) — IV-5
  C. Potomac River at Great Falls, Maryland — IV-7
  D. Rappahannock River at Fredericksburg, Virginia — IV-10
  E. York River — IV-12
    1. Mattaponi River at Beulahville, Virginia — IV-12
    2. Pamunkey River at Hanover, Virginia — IV-15
  F. James River at Richmond, Virginia — IV-15
  G. Chickahominy River at Providence Forge, Virginia — IV-17

V. NUTRIENT LOADINGS AND RELATIVE CONTRIBUTIONS — V-1
  A. Delineation of Daily Nutrient Loadings (Observed) — V-1
    1. Susquehanna River at Conowingo, Maryland — V-3
    2. Patuxent River at Route 50 (John Hanson Highway) — V-7
    3. Potomac River at Great Falls, Maryland — V-10
    4. Rappahannock River at Fredericksburg, Virginia — V-13
    5. Mattaponi River at Beulahville, Virginia — V-16
    6. Pamunkey River at Hanover, Virginia — V-19
    7. James River at Richmond, Virginia — V-22
    8. Chickahominy River at Providence Forge, Virginia — V-25
  B. Regression Analysis — V-28
    1. Analytical Framework — V-28
    2. Regression Loadings (Calculated) — V-29

TABLE OF CONTENTS

Chapter | Page

V. NUTRIENT LOADINGS AND RELATIVE CONTRIBUTIONS (Cont.)

C. Delineation of Mean Monthly Nutrient Loadings (Regression) V-55

D. Comparison of Observed Daily Loadings and Mean Monthly Loadings Based on Regression Extrapolation V-58

REFERENCES

APPENDIX

LIST OF TABLES

Number		Page
I - 1	Chesapeake Bay Nutrient Sampling Network	I-4
II - 1	Nutrient Input to Chesapeake Bay Mean Monthly Nutrient Contributions	II-7
II - 2	Nutrient Input to Chesapeake Bay Susquehanna River at Conowingo, Maryland	II-8
II - 3	Nutrient Input to Chesapeake Bay Potomac River at Great Falls, Maryland	II-9
II - 4	Nutrient Input to Chesapeake Bay James River at Richmond, Virginia	II-10
IV - 1	Mean Monthly Nutrient Concentrations	IV-1
V - 1	Average Daily Nutrient Contributions	V-1
V - 2	Seasonal Nutrient Loadings Susquehanna River at Conowingo, Maryland	V-3
V - 3	Seasonal Nutrient Loadings Patuxent River at Route 50 (John Hanson Highway)	V-7
V - 4	Seasonal Nutrient Loadings Potomac River at Great Falls, Maryland	V-10
V - 5	Seasonal Nutrient Loadings Rappahannock River at Fredericksburg, Virginia	V-13
V - 6	Seasonal Nutrient Loadings Mattaponi River at Beulahville, Virginia	V-16
V - 7	Seasonal Nutrient Loadings Pamunkey River at Hanover, Virginia	V-19
V - 8	Seasonal Nutrient Loadings James River at Richmond, Virginia	V-22
V - 9	Seasonal Nutrient Loadings Chickahominy River at Providence Forge, Virginia	V-25
V - 10	Regression Study Results Susquehanna River at Conowingo, Maryland	V-37
V - 11	Regression Study Results Patuxent River at Route 50 (John Hanson Highway)	V-38

LIST OF TABLES

Number		Page
V - 12	Regression Study Results Potomac River at Great Falls, Maryland	V-39
V - 13	Regression Study Results Rappahannock River at Fredericksburg, Virginia	V-40
V - 14	Regression Study Results Mattaponi River at Beulahville, Virginia	V-41
V - 15	Regression Study Results Pamunkey River at Hanover, Virginia	V-42
V - 16	Regression Study Results James River at Richmond, Virginia	V-43
V - 17	Regression Study Results Chickahominy River at Providence Forge, Virginia	V-44
V - 18	Nutrient Input of Susquehanna River at Conowingo, Maryland	V-46
V - 19	Nutrient Input of Potomac River at Great Falls, Maryland	V-47
V - 20	Nutrient Input of Rappahannock River at Fredericksburg, Virginia	V-48
V - 21	Nutrient Input of Mattaponi River at Beulahville, Virginia	V-49
V - 22	Nutrient Input of Pamunkey River at Hanover, Virginia	V-50
V - 23	Nutrient Input of James River at Richmond, Virginia	V-51
V - 24	Nutrient Input of Chickahominy River at Providence Forge, Virginia	V-52
V - 25	Seasonal Nutrient Loadings (Regression Extrapolation) June 1969 through October 1969	V-55
V - 26	Seasonal Nutrient Loadings (Regression Extrapolation) November 1969 through May 1970	V-56
V - 27	Seasonal Nutrient Loadings (Regression Extrapolation) June 1970 through August 1970	V-56
V - 28	Tributary Contributions (Nutrient Loadings as %)	V-57

LIST OF FIGURES

Number		Page
I - 1	Sampling Network	I-5
IV - 1	Nutrient Concentrations Susquehanna River at Conowingo, Maryland	IV-3
IV - 2	Nutrient Concentrations Patuxent River at Route 50 (John Hanson Highway)	IV-6
IV - 3	Nutrient Concentrations Potomac River at Great Falls, Maryland	IV-8
IV - 4	Nutrient Concentrations Potomac River at Great Falls, Maryland (Cont.)	IV-9
IV - 5	Nutrient Concentrations Rappahannock River at Fredericksburg, Virginia	IV-11
IV - 6	Nutrient Concentrations Mattaponi River at Beulahville, Virginia	IV-13
IV - 7	Nutrient Concentrations Mattaponi River at Beulahville, Virginia (Cont.)	IV-14
IV - 8	Nutrient Concentrations Pamunkey River at Hanover, Virginia	IV-16
IV - 9	Nutrient Concentrations James River at Richmond, Virginia	IV-18
IV - 10	Nutrient Concentrations Chickahominy River at Providence Forge, Virginia	IV-19
V - 1	Susquehanna River at Conowingo, Maryland Actual Daily Nutrient Loadings	V-4
V - 2	Susquehanna River at Conowingo, Maryland Actual Daily Nutrient Loadings (Cont.)	V-5
V - 3	Susquehanna River at Conowingo, Maryland Actual Daily Nutrient Loadings (Cont.)	V-6
V - 4	Patuxent River at Route 50 (John Hanson Highway) Actual Daily Nutrient Loadings	V-8
V - 5	Patuxent River at Route 50 (John Hanson Highway) Actual Daily Nutrient Loadings (Cont.)	V-9
V - 6	Potomac River at Great Falls, Maryland Actual Daily Nutrient Loadings	V-11

LIST OF FIGURES

Number		Page
V - 7	Potomac River at Great Falls, Maryland Actual Daily Nutrient Loadings (Cont.)	V-12
V - 8	Rappahannock River at Fredericksburg, Virginia Actual Daily Nutrient Loadings	V-14
V - 9	Rappahannock River at Fredericksburg, Virginia Actual Daily Nutrient Loadings (Cont.)	V-15
V - 10	Mattaponi River at Beulahville, Virginia Actual Daily Nutrient Loadings	V-17
V - 11	Mattaponi River at Beulahville, Virginia Actual Daily Nutirent Loadings (Cont.)	V-18
V - 12	Pamunkey River at Hanover, Virginia Actual Daily Nutrient Loadings	V-20
V - 13	Pamunkey River at Hanover, Virginia Actual Daily Nutrient Loadings (Cont.)	V-21
V - 14	James River at Richmond, Virginia Actual Daily Nutrient Loadings	V-23
V - 15	James River at Richmond, Virginia Actual Daily Nutrient Loadings (Cont.)	V-24
V - 16	Chickahominy River at Providence Forge, Virginia Actual Daily Nutrient Loadings	V-26
V - 17	Chickahominy River at Providence Forge, Virginia Actual Daily Nutrient Loadings (Cont.)	V-27
V - 18	Nutrient Load - Streamflow Relationship, Susquehanna River at Conowingo, Maryland (T.PO_4 as PO_4 versus flow)	V-31
V - 19	Nutrient Load - Streamflow Relationship, Susquehanna River at Conowingo, Maryland (Pi as PO_4 versus flow)	V-32
V - 20	Nutrient Load - Streamflow Relationship, Susquehanna River at Conowingo, Maryland (T.K.N. as N versus flow)	V-33
V - 21	Nutrient Load - Streamflow Relationship, Susquehanna River at Conowingo, Maryland (NO_2 + NO_3 as N versus flow)	V-34

LIST OF FIGURES

Number		Page
V - 22	Nutrient Load - Streamflow Relationship, Susquehanna River at Conowingo, Maryland (NH_3 as N versus flow)	V-35
V - 23	Nutrient Load - Streamflow Relationship, Susquehanna River at Conowingo, Maryland (T.O.C. versus flow)	V-36
V - 24	Nitrogen Input to Chesapeake Bay	V-53
V - 25	Phosphorus Input to Chesapeake Bay	V-54
V - 26	River Discharges (Mean monthly versus observed)	V-60
V - 27	River Discharges (Cont.)	V-61
V - 28	Susquehanna River at Conowingo, Maryland Mean Monthly Nutrient Loadings (Regression) versus Actual Daily Nutrient Loadings (Observed)	V-62
V - 29	Susquehanna River at Conowingo, Maryland Mean Monthly Nutrient Loadings (Regression) versus Actual Daily Nutrient Loadings (Observed) (Cont.)	V-63
V - 30	Susquehanna River at Conowingo, Maryland Mean Monthly Nutrient Loadings (Regression) versus Actual Daily Nutrient Loadings (Observed) (Cont.)	V-64

CHAPTER I

INTRODUCTION

A. PURPOSE AND SCOPE

A perplexing problem in water quality analysis is the determination of the effects of waste discharges upon the assimilative capacity of the receiving waters. Domestic, industrial, and agricultural wastes, which contribute to progressive stream fertilization, ultimately lead to excessive algal growth. The nutrients, especially nitrogen and phosphorus, which normally contribute to dense algal growth and resultant stream deterioration, have been related to recently accelerated eutrophication observed in the Chesapeake Bay.

In order to assess the degree of eutrophication in the Bay and delineate the nutrient sources responsible for this condition, it was necessary to determine the nutrient contributions from the major tributary watersheds. This factor led to the establishment of the Chesapeake Bay Nutrient Input sampling network. Determination of the sources of nutrient inputs and their effect on the resources of the Bay is an important step in the development of a management scheme for future use in nutrient control.

Consequently, an intensive water quality survey of the Chesapeake Bay's major tributary watersheds was conducted to determine the primary sources and relative contribution of nutrients affecting the Chesapeake Bay from nontidal areas. The principal objectives of this study were to:

1. Determine the extent of existing nutrient loadings to the Chesapeake Bay from major tributary watersheds.

2. Identify streams contributing significant nutrient loadings to the Chesapeake Bay.
3. Determine seasonal trends in nutrient input to the Chesapeake Bay.
4. Determine average nutrient loadings and concentrations for each tributary watershed.
5. Establish relationships between nutrient load and stream flow for every tributary (regression analysis).
6. Identify portions of the Chesapeake Bay high in nutrients.
7. Consider the impact of continued nutrient enrichment on the Bay ecosystem.
8. Obtain sufficient data on which to base future management decisions on nutrient control from pertinent watersheds.

B. DESCRIPTION OF THE SAMPLING NETWORK

In order to account for the seasonal variations in the nutrient loadings from major watersheds (i.e., effect of seasonal river discharges), the Annapolis Field Office, Region III, Environmental Protection Agency, conducted this extensive nutrient survey during a 15-month period, June 1969 to August 1970. The survey was confined to the following tributary watersheds: the Susquehanna, the Patuxent, the Potomac, the Rappahannock, the Mattaponi, the Pamunkey, the Chickahominy, and the James.

A sampling network was developed which consisted of eight stations strategically located within the Chesapeake Bay's major tributary watersheds. The following criteria were used in locating the sampling stations:

(1) One station at at or near the fall line of each major tributary watershed -

- a. Susquehanna River
- b. Patuxent River
- c. Potomac River
- d. Rappahannock River
- e. Mattaponi River
- f. Pamunkey River
- g. Chickahominy River
- h. James River

(2) Stations located at or near the United States Geological Survey (USGS) gaging stations

A brief description of each sampling station is given in Table I - 1 and the locations shown in Figure I - 1. Samples were normally obtained weekly during the entire study period.

Table I - 1

CHESAPEAKE BAY NUTRIENT SAMPLING NETWORK

Station Code	Station Name	USGS Gage Reference
CW	Susquehanna River at Conowingo, Md.	-
PJ	Patuxent River at Route 50 (John Hanson Highway)	-
GF	Potomac River at Great Falls, Md.	1-6465
RF	Rappahannock River at Fredericksburg, Va.	1-6680
MB	Mattaponi River at Beulahville, Va.	1-6745
PH	Pamunkey River at Hanover, Va.	1-6730
CH	Chickahominy River at Providence Forge, Va.	2-0425
JR	James River at Richmond, Va.	2-375

A weekly sampling schedule accounted for 505 samples which were analyzed for the following parameters: Total Phosphorus as PO_4, Inorganic Phosphorus as PO_4, Total Kjeldahl Nitrogen as N, Ammonia Nitrogen as N, Nitrite-Nitrate as N and Total Organic Carbon.

C. AUTHORITY

This report was prepared under the provision of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.), which directed the Secretary of the Interior* to develop programs for eliminating pollution of interstate waters and improving the condition of surface and ground waters.

D. ACKNOWLEDGEMENTS

The cooperation of the following governmental agency and state organizations has enabled the Annapolis Field Office (AFO) to complete

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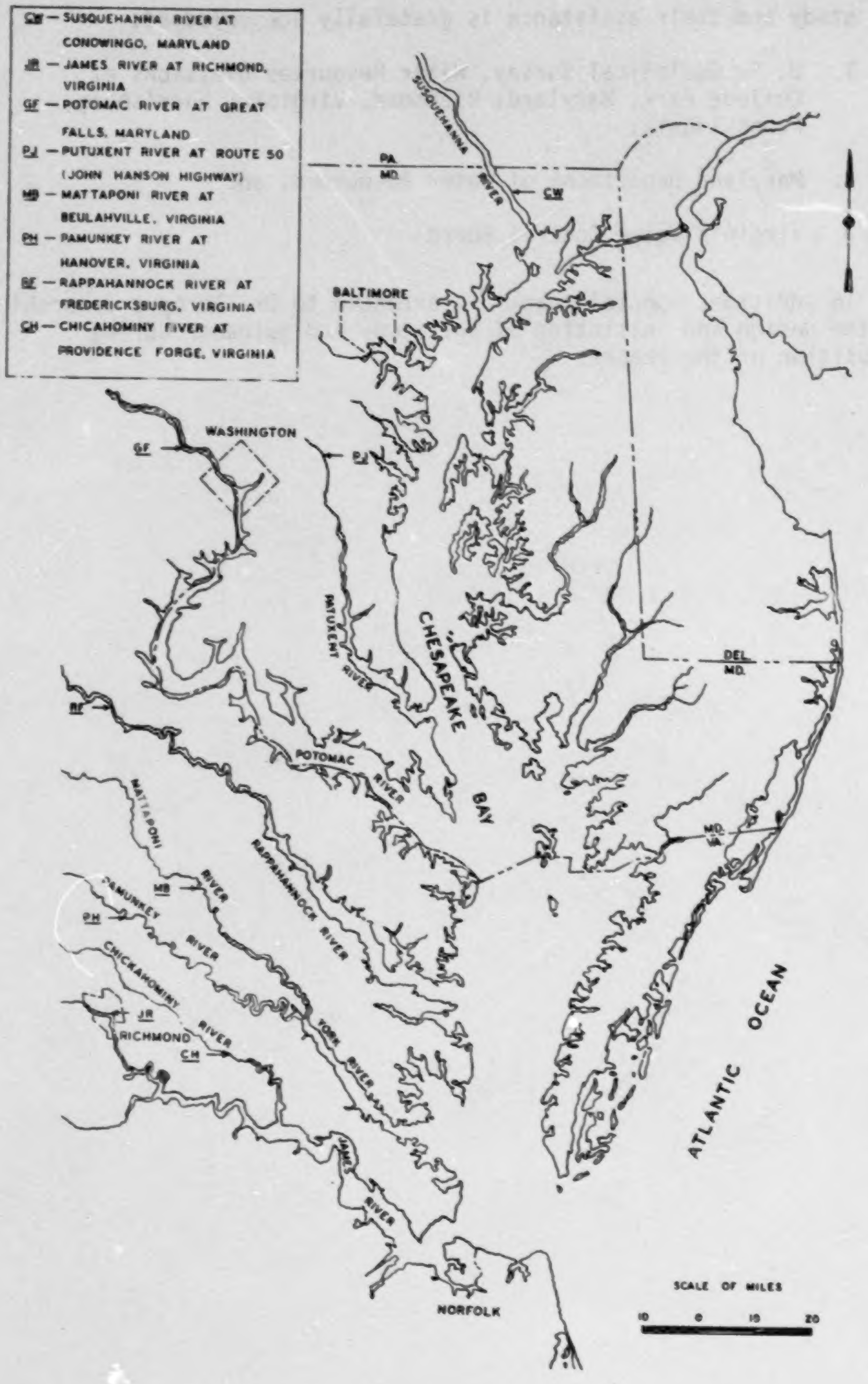
* now Administrator, EPA

I-5

SAMPLING NETWORK



CW — SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND
JR — JAMES RIVER AT RICHMOND, VIRGINIA
GF — POTOMAC RIVER AT GREAT FALLS, MARYLAND
PJ — PUTUXENT RIVER AT ROUTE 50 (JOHN HANSON HIGHWAY)
MB — MATTAPONI RIVER AT BEULAHVILLE, VIRGINIA
PH — PAMUNKEY RIVER AT HANOVER, VIRGINIA
RF — RAPPAHANNOCK RIVER AT FREDERICKSBURG, VIRGINIA
CH — CHICAHOMINY FIVER AT PROVIDENCE FORGE, VIRGINIA
SUSQUEHANNA RIVER
PA.
MD.
CW
BALTIMORE
WASHINGTON
GF
PJ
PATUXENT RIVER
CHESAPEAKE BAY
DEL.
MD.
RF
POTOMAC RIVER
MATTAPONI RIVER
MB
RAPPAHANNOCK RIVER
PAMUNKEY RIVER
PH
CHICKAHOMINY RIVER
JR
RICHMOND
CH
YORK RIVER
JAMES RIVER
MD.
VA.
ATLANTIC OCEAN
NORFOLK
SCALE OF MILES
10
0
10
20

this study and their assistance is gratefully acknowledged:

1. U. S. Geological Survey, Water Resources Divisions at College Park, Maryland; Richmond, Virginia; Harrisburg, Pennsylvania;

2. Maryland Department of Water Resources, and

3. Virginia Water Control Board.

In addition, special thanks is extended to Dr. Norbert Jaworski for the design and initiation of the study and guidance during composition of the report.

CHAPTER II

SUMMARY AND CONCLUSIONS

A detailed study of the nutrient contributions to the Chesapeake Bay from major tributary watersheds was undertaken during the period of June 1969 to August 1970. The study findings are presented below:

1. The average measured concentration of nutrients for the eight major watersheds varied as follows:

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
	mg/l					
Susquehanna River at Conowingo, Md.	0.18	0.12	0.67	0.91	0.23	3.64
Patuxent River at Route 50 (John Hanson Highway)	2.77	1.90	1.68	1.35	1.00	7.72
Potomac River at Great Falls, Md.	0.50	0.22	0.87	1.05	0.17	6.42
Rappahannock River at Fredericksburg, Va.	0.25	0.13	0.57	0.52	0.10	4.83
Mattaponi River at Beulahville, Va.	0.16	0.13	0.58	0.11	0.07	8.08
Pamunkey River at Hanover, Va.	0.18	0.13	0.53	0.19	0.12	6.15
Chickahominy River at Providence Forge, Va.	0.57	0.39	0.73	0.25	0.07	10.53
James River at Richmond, Va.	0.20	0.13	0.64	0.66	0.13	5.51

Although the average measured nutrient concentrations for the Patuxent River were generally the highest among the eight major tributaries, the corresponding nutrient loadings (lbs/day) represent minor contributions due to the relatively lower river discharge (as compared to the Susquehanna, the Potomac, and the James).

2. On an average daily basis for the entire study period (observed data), the nutrient loadings entering the Chesapeake Bay from the major tributary watersheds are as follows:

Nutrient Loadings (lbs/day)

Tributary Watershed	T. PO$_4$ as PO$_4$	Pi	TKN as N	NO$_2$ + NO$_3$ as N	NH$_3$ as N	TOC
Susquehanna River	59,000	34,000	130,000	230,000	42,000	576,000
Potomac River	45,000	19,000	69,000	87,000	12,000	363,000
James River	7,000	5,000	19,000	15,000	5,000	169,000
Patuxent River	5,000	3,000	4,000	2,000	2,000	18,000
Rappahannock River	3,000	2,000	6,000	5,400	1,000	40,000
Pamunkey River	1,000	1,000	3,000	1,000	600	36,000
Mattaponi River	1,000	500	1,000	400	300	21,000
Chickahominy	600	400	900	200	100	15,000

The average daily nutrient input of the major tributary watersheds to the Chesapeake Bay for the entire study period (regression extrapolation using mean monthly flows) is as follows:

Nutrient Loadings (lbs/day)

Tributary Watershed*	T. PO$_4$ as PO$_4$	Pi	TKN as N	NO$_2$ + NO$_3$ as N	NH$_3$ as N	TOC
Susquehanna River	33,000	20,000	93,000	153,000	29,000	513,000
Potomac River	23,000	9,900	35,000	57,000	6,000	267,000
James River	7,100	4,200	18,000	15,500	4,200	133,000
Rappahannock River	1,600	900	3,900	3,600	600	29,000
Pamunkey River	1,500	900	3,000	1,700	700	37,000
Mattaponi River	500	450	1,500	400	250	20,500
Chickahominy River	500	400	900	200	100	12,000

* Insufficient flow data for Patuxent extrapolation

Comparison of the loadings (observed versus regression extrapolation) show generally higher loadings when the observed daily data is averaged for the study period. The average daily nutrient input based on regression extrapolation using mean monthly flows is a more accurate representation of the situation since use of mean monthly flows eliminates the biased nature of extreme periods of flow during which sampling may have occurred.

3. On the basis of mean monthly nutrient contributions (regression extrapolation) over the entire 15-month study period, the primary sources of nutrients entering the Chesapeake Bay emanate from three major watersheds--the Susquehanna, the Potomac, and the James. Actual percentages for all of the watersheds sampled are shown below:

Loadings (lbs/day) as %

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	NO_2 + NO_3 as N	NH_3 as N	TOC
Susquehanna River	49	54	60	66	71	51
Potomac River	33	27	23	25	15	27
James River	12	13	10	6	11	12
Rappahannock River	2	2	3	1	1	3
Pamunkey River	2	2	2	1	1	4
Mattaponi River	1	1	1	<1	<1	2
Chickahominy River	1	1	1	<1	<1	1

4. Seasonal variations in the percentage of nutrient contribution of the total nontidal nutrient input to the Chesapeake Bay from all sources sampled are shown below:

Seasonal Nutrient Contribution as %

Time Period	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
June 1969 through October 1969	14	14	19	14	20	19
November 1969 through May 1970	67	73	59	68	57	60
June 1970 through August 1970	19	13	22	18	23	21

5. During the significant period of November 1969 through May 1970 when the majority of nutrients were transported into the Chesapeake Bay via nontidal discharges, the primary nutrient loadings again emanated from three major watersheds--the Susquehanna, the Potomac, and the James as indicated in the following table:

Tributary Contributions
(Nutrient Loadings as %)

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
Susquehanna River	54	60	62	66	72	55
Potomac River	34	26	23	26	16	25
James River	7	8	10	5	9	12
Rappahannock River	3	3	3	2	<2	3
Pamunkey River	1	1	1	<1	<1	2
Mattaponi River	<1	1	<1	<1	<1	2
Chickahominy River	<1	1	<1	<1	<1	<1

As presented, the tributary contributions reflect two distinct observations which can be made in regard to nutrient enrichment of the Chesapeake Bay: (1) the predominant influence of three principal watersheds on the nutrient balance of the Chesapeake Bay--the Susquehanna, the Potomac and the James and (2) the seasonal nature of nutrient enrichment of the Chesapeake Bay whereby the majority of nutrients transported into the Chesapeake Bay via nontidal discharges occurred during the period of November 1969 through May 1970.

Although the majority of nutrients are transported into the Chesapeake Bay during the above period, more significance may be attributed to periods of low flow (and high temperature) during which high resident times result in significant algal blooms. Evaluation, therefore, of nutrient transport in the Chesapeake Bay from nontidal sources is not accomplished herein.

These three tributary watersheds are the major factors responsible for the Chesapeake Bay's nutrient problems. Control of nutrients from these major watersheds, especially the Susquehanna, should result in a restored nutrient balance in the Bay.

6. The cumulative nutrient inputs from the major tributary watersheds to the Chesapeake Bay based on regression analyses using mean monthly flow data for the entire study period are presented in Table II - 1.

7. Mean monthly nutrient contributions (lbs/day) from the three major tributary watersheds are presented in Tables II - 2, II - 3, and II - 4.

8. Nutrient loadings (lbs/day) are highly related to river discharge. For example, on October 22, 1969, with a river discharge of

4,300 cfs, approximately 3,200 lbs/day of total phosphorus as PO_4 and 15,000 lbs/day of $NO_2 + NO_3$ nitrogen as N entered the Chesapeake Bay from the Susquehanna River at Conowingo, Maryland, while on April 3, 1970, with a river discharge of 264,000 cfs, approximately 683,000 and 1,400,000 lbs/day of total phosphorus as PO_4 and $NO_2 + NO_3$ nitrogen as N, respectively, entered the Bay at Conowingo, Maryland. Thus, the relationship between river discharge and nutrient loadings, especially $NO_2 + NO_3$ as N, is apparent. High $NO_2 + NO_3$ as N loadings are indicative of land runoff as contrasted to TKN as N loadings which are attributable mainly to treatment plant effluents entering the waterways. Conversely, total phosphorus as PO_4 is more difficult to characterize since it tends to adsorb to particles and sediments in the water. During low flow periods, phosphorus is retained in bottom deposits in the stream channel. As a result, a substantial portion of the PO_4 is unavailable due to sedimentation. During high flow periods, scouring may occur in the waterway, thus releasing the nutrients retained in the sediment and transporting them downstream and ultimately to the Chesapeake Bay.

Table II - 1
Nutrient Input to Chesapeake Bay*
Mean Monthly Nutrient Contributions

Date	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	26,000	13,000	88,000	102,000	25,000	553,000
07/69	25,000	13,000	85,000	85,000	23,000	558,000
08/69	83,000	44,000	188,000	178,000	55,000	1,400,000
09/69	18,000	8,200	55,000	54,000	14,000	372,000
10/69	10,000	4,500	39,000	30,000	11,000	247,000
11/69	33,000	17,000	105,000	132,000	29,000	638,000
12/69	55,000	29,000	151,000	196,000	40,000	974,000
01/70	64,000	33,000	154,000	180,000	40,000	1,077,000
02/70	149,000	83,000	306,000	529,000	76,000	1,960,000
03/70	101,000	55,000	227,000	364,000	58,000	1,482,000
04/70	283,000	175,000	483,000	1,079,000	117,000	3,200,000
05/70	69,000	38,000	177,000	254,000	47,000	1,100,000
06/70	33,000	15,000	96,000	116,000	27,000	593,000
07/70	39,000	18,000	104,000	132,000	29,000	663,000
08/70	17,000	8,000	59,000	58,000	17,000	360,000
TOTAL	1,000,000	586,000	2,300,000	3,489,000	608,000	15,200,000
AVG. MO.	67,000	37,000	155,000	230,000	40,000	1,000,000

* Susquehanna, Potomac, Rappahannock, Pamunkey, Mattaponi, James, Chickahominy (insufficient flow data for Patuxent extrapolation)

Table II - 2
Nutrient Input to Chesapeake Bay*
Susquehanna River at Conowingo, Maryland

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	19,200	15,000	8,000	63,000	82,000	21,000	327,000
07/69	14,900	11,000	6,000	51,000	61,000	17,000	258,000
08/69	18,000	14,000	8,000	60,000	76,000	20,000	308,000
09/69	6,300	4,000	2,000	25,000	23,000	9,000	115,000
10/69	5,000	3,000	1,000	21,000	18,000	8,000	93,000
11/69	25,900	22,000	12,000	81,000	114,000	26,000	433,000
12/69	31,100	28,000	16,000	95,000	141,000	30,000	514,000
01/70	18,700	15,000	8,000	62,000	79,000	21,000	319,000
02/70	67,200	75,000	46,000	181,000	335,000	52,000	1,000,000
03/70	50,300	52,000	31,000	141,000	242,000	42,000	807,000
04/70	132,800	176,000	119,000	319,000	723,000	86,000	2,000,000
05/70	41,200	40,000	24,000	120,000	193,000	37,000	670,000
06/70	20,400	17,000	9,000	66,000	87,000	22,000	346,000
07/70	20,400	17,000	9,000	66,000	87,000	22,000	346,000
08/70	10,600	7,000	4,000	38,000	42,000	14,000	187,000
TOTAL	482,000	496,000	303,000	1,400,000	2,300,000	427,000	7,700,000
AVG. MO.	32,133	33,000	20,000	93,000	153,000	29,000	513,000

* Regression extrapolation using mean monthly flows

Table II - 4
Nutrient Input to Chesapeake Bay *
James River at Richmond, Virginia

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	3,255	3,100	1,900	10,000	11,000	1,600	83,000
07/69	4,567	4,700	2,900	14,000	14,000	3,000	116,000
08/69	21,710	34,500	19,000	68,000	47,000	22,000	524,000
09/69	2,402	2,100	1,300	7,000	8,000	1,000	62,000
10/69	1,568	1,000	700	5,000	6,000	500	37,000
11/69	1,622	1,300	800	5,000	6,000	500	42,000
12/69	4,607	4,700	2,900	15,000	14,000	3,000	116,000
01/70	10,820	14,000	8,300	34,000	27,000	8,000	266,000
02/70	10,980	14,000	8,300	35,000	27,000	8,000	267,000
03/70	6,023	6,700	4,000	19,000	17,000	4,000	151,000
04/70	10,070	13,000	7,600	32,000	26,000	7,000	246,000
05/70	4,892	5,100	3,200	15,000	15,000	3,000	123,000
06/70	1,184	1,000	600	3,000	5,000	500	31,000
07/70	1,155	1,000	600	3,000	5,000	500	31,000
08/70	1,258	1,000	600	4,000	5,000	500	33,000
TOTAL	86,113	107,000	63,000	269,000	233,000	63,000	2,000,000
AVG.MO.	5,740	7,100	4,200	18,000	15,500	4,200	133,000

* Regression extrapolation using mean monthly flows

Table II - 3
Nutrient Input to Chesapeake Bay*
Potomac River at Great Falls, Maryland

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	2,685	6,000	2,000	11,000	7,000	2,000	96,000
07/69	2,954	6,000	2,000	12,000	7,000	2,000	102,000
08/69	8,461	19,000	8,000	32,000	37,000	6,000	246,000
09/69	4,812	10,000	4,000	19,000	16,000	3,000	155,000
10/69	2,327	5,000	2,000	10,000	5,000	2,000	86,000
11/69	3,626	8,000	3,000	15,000	10,000	2,000	123,000
12/69	7,952	18,000	7,000	30,000	34,000	5,000	233,000
01/70	11,958	28,000	12,000	43,000	63,000	8,000	326,000
02/70	21,390	52,000	24,000	73,000	152,000	13,000	524,000
03/70	16,104	38,000	17,000	57,000	99,000	10,000	416,000
04/70	34,593	86,000	43,000	113,000	315,000	21,000	777,000
05/70	9,216	21,000	9,000	34,000	42,000	6,000	263,000
06/70	6,204	14,000	5,000	24,000	23,000	4,000	191,000
07/70	8,627	20,000	8,000	32,000	38,000	6,000	250,000
08/70	3,606	8,000	3,000	15,000	10,000	2,000	123,000
TOTAL	144,515	339,000	149,000	520,000	858,000	92,000	4,000,000
AVG. MO.	9,634	23,000	9,900	35,000	57,000	6,000	267,000

* Regression extrapolation using mean monthly flow

9. Nutrient concentrations (mg/l) and river discharges (cfs) showed interesting relationships which were found to be dependent on several factors, i.e. particular nutrient within a particular watershed, time of the year, and weather conditions which affected normal river discharge. Unique relationships were observed for each nutrient within each tributary watershed and generalizations as to direct or indirect dependence of nutrient concentrations on flow could not be obtained from the survey data. The nutrient concentration - river discharge relationship for each nutrient in the eight major tributary watersheds is presented in Chapter IV. A brief summary of the nutrient concentration - river discharge relationships for the Susquehanna River, the Potomac River, and the James River is presented as follows:

a. Susquehanna River at Conowingo, Maryland (see Figure IV - 1)

Considerably higher river discharge during the period of November 1969 to May 1970 resulted in higher total phosphorus (as PO_4) and inorganic phosphorus concentrations. Periods of higher than normal flow resulted in total and inorganic phosphorus surges from the upper Susquehanna River Basin. A direct relationship between total and inorganic phosphorus concentrations (as PO_4) and river discharge is evident. Since these high concentrations occurred during periods of higher than normal flow, it appears that the relatively short residence time within the impoundment did not permit the occurrence of a substantial amount of deposition or biological uptake.

In addition, the organic phosphorus buildup (TPO_4 - Pi) appears to be occurring during the summer months, which is indicative of algal biomass enrichment normally associated with summer conditions.

Concentrations of NO_2 + NO_3 showed extreme dependence on river discharge. High $NO_2 + NO_3$ concentrations during the winter months are primarily the direct result of land runoff associated with the high river discharge. A secondary reason for these high levels may be the reduced detention time by Conowingo Dam during high flow periods. A direct relationship between $NO_2 + NO_3$ concentrations and river discharge is evident.

TKN concentrations, however, decreased during the period of higher flow. These reduced TKN concentrations are indicative of a flushing type response in the river whereby the organic load is diluted by the increased river discharge. An indirect relationship between TKN concentrations and river discharge is evident.

The direct relationship between $NO_2 + NO_3$ concentrations and river discharge coupled with the indirect relationship between TKN concentrations and river discharge in the Susquehanna River is interesting. During the summer months (a period of low flow) low nitrite-nitrate concentrations coupled with higher TKN concentrations suggest that algal cells are readily utilizing the nitrate form of nitrogen and converting it to TKN.

Concentrations of ammonia nitrogen remained relatively uniform when compared to other nutrient concentrations. High NH_3 concentrations were observed in the months of January and February 1970, and June and July 1970.

b. Potomac River at Great Falls, Maryland (see Figure IV - 2)

Total and inorganic phosphorus concentrations remained generally uniform except for extreme variations in concentration during December 1969 and February, April, May and June 1970. These extreme surges generally correspond to days of higher than normal flow.

The organic phosphorus fraction (T.PO_4 - Pi) was higher during the months of June through October 1969 (in the range of 0.2 to 0.5 mg/l), and especially low during the months of December 1969 through February 1970 (<0.1 mg/l). The algal biomass may reflect this high organic fraction during the summer months with the inorganic phosphorus utilized to a greater extent than in the winter months.

Concentrations of $NO_2 + NO_3$ showed extreme dependence on river discharge. High $NO_2 + NO_3$ concentrations during the winter months are primarily the direct result of land runoff associated with the high river discharge. A secondary reason for these high levels may be the reduced detention time at Conowingo Dam during high flow periods. During the summer months high peaks of $NO_2 + NO_3$ concentrations were observed. A combination of excessive river flows and nitrification was probably responsible for these surges. A direct relationship between $NO_2 + NO_3$ concentrations and river discharge is evident.

Concentrations of TKN also showed extreme variations during the study period. In general, TKN appeared to have an indirect relationship to flow. Reduced TKN concentrations during high flow periods are indicative of the dilution effect in the river whereby the organic load is dispersed by the increased runoff.

The direct relationship between $NO_2 + NO_3$ concentrations and river flows coupled with the indirect relationship between TKN concentrations and flows in the Potomac River correspond to the similar observations in the Susquehanna River. During the low flow summer months low $NO_2 + NO_3$ concentrations coupled with higher TKN concentrations suggest that algal cells are readily utilizing the nitrate form of nitrogen and converting it to TKN.

Ammonia nitrogen concentrations remained relatively uniform throughout most of the study period. During the summer months most of the NH_3 appeared to be oxidized to nitrite-nitrate nitrogen which was then converted into organic nitrogen in the algal cellular material, i.e., a greater organic fraction ($TKN - NH_3$) during the summer than in the winter months.

C. James River at Richmond, Virginia (see Figure IV - 9)

Both total and inorganic phosphorus concentrations in the James River were relatively uniform throughout the study period. Slight increases in concentrations occurred, however, during the winter and spring months when river flows were substantially higher.

Concentrations of $NO_2 + NO_3$ nitrogen, however, appeared to decrease during the high flow periods of January through May 1970, although considerable fluctuations were noted throughout the study period.

With regard to TKN concentrations, a drastic variation in TKN levels between 0.2 mg/l and 2.0 mg/l was observed with seasonal patterns not being evident.

Ammonia nitrogen concentrations were generally higher during the winter and spring with maximum levels exceeding 0.3 mg/l. Biostimulation may have been a significant factor from July to October 1969 since nitrate levels were at a minimum while an abundance of organic nitrogen was present during that period.

10. Most of the water quality problems in the Bay are similar to those in other comparable areas of the United States but are compounded because the area is largely tidal. The Bay receives its share of municipal and industrial wastes, the primary effects of which are immediate water quality impairment in several areas. However, the

secondary effects create a more widespread insidious water quality problem--that of eutrophication in a number of rivers discharging into the Chesapeake Bay. This progressive eutrophication of the Bay's tributaries, caused by the increase in nutrient quantities discharged into waterways via waste discharge and land runoff, threatens the water quality and biota of the Bay.

Flows from the eight major tributary watersheds increase the naturally high nutrient levels and biological productivity of the Chesapeake Bay. These flows include abundant amounts of plant nutrients such as inorganic nitrogen, phosphorus and carbon which are incorporated into organic matter by aquatic plants.

In early stages, nutrient enrichment may result in beneficial conditions (i.e., increase in fish productivity, zooplankton, etc.). However, the advanced stages lower dissolved oxygen levels, interfere with recreational uses of water, affect drinking water taste and result in blooms of undesirable blue-green algae. The more abundant the nutrient supply, the greater potential there is for dense vegetation. Thus, control of eutrophication in the Chesapeake Bay focused on control of three nutrients--nitrogen, phosphorus, and carbon.

The primary sources of nutrients to the Chesapeake Bay are three nontidal tributary watersheds--the Susquehanna, the Potomac, and the James. Of primary concern is the control of nutrients from these upstream sources--especially the Susquehanna River, since it contributes in excess of 50% of all nutrients entering the Chesapeake Bay. During the significant period of November 1969 through May 1970, the Susquehanna River Basin contributed 54% of the total phosphorus, 60% of the inorganic phosphorus, 62% of the total Kjeldahl nitrogen, 66% of the nitrite-nitrate nitrogen, 72% of the ammonia nitrogen, and 55% of the total organic carbon entering the Bay.

As these upstream sources are brought under control during critical periods--especially the Susquehanna River--commensurate reduction in nuisance conditions in the Chesapeake Bay will result.

11. Identification of the Susquehanna River as the major contributor to the Chesapeake Bay's nutrient load resulted in the implementation of an intensive nutrient survey within the Susquehanna Basin to locate individual sources and their degree of controllability. The survey area extends from the Susquehanna River at Sunbury, Pennsylvania to Conowingo, Maryland. It was begun in June 1971 and was completed in July 1972. A report of the findings will follow.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

A. CHESAPEAKE BAY

The geographic area that drains to the Chesapeake Bay encompasses approximately 70,000 square miles including the District of Columbia, nearly all of Maryland, 65 percent of Virginia, 50 percent of Pennsylvania, 12 percent of New York and 12 percent of West Virginia, as well as a portion of Delaware.

The tidewater portion of the Chesapeake Bay Basin covers an area of approximately 8,400 square miles in the State of Maryland and the Commonwealth of Virginia. The combined tidal shoreline is approximately 4,600 miles in length, of which 3,400 miles are in Maryland and 1,200 miles are in Virginia. The Bay is approximately 190 miles in length and varies in width from 4 miles at Sandy Point in the vicinity of the Chesapeake Bay Bridge to approximately 30 miles at its widest point near Pocomoke Sound. The average depth of the Bay is approximately 28 feet and the deepest point is 174 feet, off the southern tip of Kent Island.

The Chesapeake Bay receives freshwater inflows from 150 tributaries, of which the following are major watersheds: the Susquehanna, the Patapsco, the West, the Patuxent, the Potomac, the Rappahannock, the York, the Chickahominy and the James on the western shore and the Chester, the Choptank, the Nanticoke, the Wicomico and the Pocomoke on the eastern shore.

The major river in the drainage area is the Susquehanna, the largest river basin on the Atlantic Coast. The Potomac and James River Basins are the second and third largest, respectively, draining into the Bay. Together, these three river systems account for 80 percent of the drainage into the Chesapeake Bay. The dominant feature of the Basin is, of course, the Chesapeake Bay, the largest tidal estuary in the United States.

The population of the Chesapeake Bay Basin area was 2.6 million in 1960 and is expected to reach 4.1 million by 1985 and 5.3 million by the year 2000. It contains rich farmlands, vast woodlands and intensively developed industrial areas which are steadily increasing in importance.

The Chesapeake Bay, the biggest and probably the richest of the 500 odd estuaries in the United States, is regarded as one of the most valuable estuaries in the world. Commercial fishing, which provides a means of livelihood for approximately 20,000 people, and sport fishing, enjoyed by many thousands, actually comprise only a small part of the value of the Bay as a natural resource. Waterborne commerce, totaling 150 million tons annually, contributes in large measure to the economy of 11 tributary states.

This extensive use of the Bay--fishing, recreation, navigation, waste assimilation--has resulted in an increasingly greater strain on the ability of the Bay to accomodate the diverse and often conflicting demands which are made upon it.

B. Tributary Watersheds

The major tributary watersheds - the Susquehanna, the Patuxent, the Potomac, the Rappahannock, the Mattaponi, the Pamunkey, the James, and the Chickahominy - are the subject of this report.

1. Susquehanna River Basin

The Susquehanna River Basin, which drains directly into the Chesapeake Bay, lies within four physiographic provinces: the Applachian, the Ridge and Valley, the Piedmont, and the Blue Ridge. The basin, 250 miles in length and 170 miles in width, embraces a draingage drainage area of 27,510 square miles. It is the largest river basin on the Atlantic Seaboard and second largest east of the Mississippi. It is bounded by the drainage basins of (1) Lake Ontario and the Mohawk on the north (2) the Potomac River on the south (3) the Delaware River on the east and (4) the Genesee River and the Ohio River on the west.

The terrain of the study area, confined to the lower portion of the Susquehanna River extending from Harrisburg to the Chesapeake Bay--a distance of approximately 67 miles located within the Piedmont Region--is characterized by low rolling hills. The uplands are formed by crystalline and metamorphic rocks of Precambrian and early Paleozoic Age. In the northern part of the Piedmont is a broad area underlain by sandstone shale of Triassic Age.

The study area has a temperate climate with four sharply defined seasons. The average annual precipitation amounts to approximately 42 inches, with about 10 percent occurring as snow.

The major river in the Basin is, of course, the Susquehanna River, which is formed at Sunbury, Pennsylvania, by the confluence of its North and West Branches. From Sunbury, it flows southeasterly 39 miles to Duncannon where it is joined by the Juniata River, its principal tributary; it then flows 84 miles to the Chesapeake Bay. The North Branch rises in Lake Otsego in southcentral New York and flows southwesterly 170 miles to Athens, Pennsylvania, where it is joined by the Chemung River. From that point, it flows 100 miles generally southeasterly to Pittston, Pennsylvania, and then 65 miles southwesterly to its confluence with the West Branch at Sunbury. The West Branch rises on the Allegheny Plateau in central Pennsylvania. It flows easterly and southerly across the plateau and through the Allegheny Front for a distance of 240 miles to join the North Branch at Sunbury.

The average flow of the Susquehanna River is approximately 25 billion gallons per day which represents more than 50% of the freshwater inflow to the Chesapeake Bay. The biota of the upper Bay is dependent to a large extent on this freshwater inflow.

When compared to other areas around it, the Susquehanna River Basin is relatively undeveloped. The resident population is small and the economy lagging.

2. Patuxent River Basin

The Patuxent River Basin, the largest river basin loacated entirely within the State of Maryland, embraces a drainage area of approximately

930 square miles. The basin extends for 110 miles in a southeasterly and then southerly direction from its origin in Parris Ridge to its mouth on the Chesapeake Bay. The basin lies in both the Piedmont Plateau and the Coastal Plain physiographic provinces.

The basin lies between the metropolitan complexes of Washington, D. C. and Baltimore, Maryland. Urbanization, occurring in the upper drainage area near the headwaters in Howard and Montgomery Counties, is transforming this area into cities and suburbs. The lower area, however, is retaining its rural character. The population within the Patuxent River Basin is expected to grow from a 1960 level of 135,000 to 684,000 by the year 2000.

The upper or headwaters region of the Patuxent, lying in Howard and Montgomery Counties, is characterized by narrow, swift, clear streams. The middle region, extending from the Fall Line at Laurel to Wayson's Corner, occupies portions of Anne Arundel and Prince George's Counties. It is characterized by wide, flat, swampy flood plains and a sluggish stream. Most of the wastewater effluents originating in the basin are discharged into this reach of the river.

The lower region, below Hardesty, is a tidal estuary characterized by unforested marsh lands, the result of the silting up of the original estuary.

The major tributaries of the Patuxent River are the Little Patuxent and the Western Branch, with drainage areas of 160 and 110 square miles, respectively.

Land use in the Patuxent River Basin has been predominately agricultural over the entire drainage area since the days of the early settlers. Today the most important economic activity in the Patuxent

River Basin continues to be farming. Approximately 245,000 acres of the basin are estimated to be utilized for this purpose.

3. Potomac River Basin

The Potomac River Basin, which includes the District of Columbia and parts of Maryland, Pennsylvania, Virginia, and West Virginia, with a total drainage area of 14,670 square miles, lies in five physiographic provinces: Coastal Plain, Piedmont Plateau, Blue Ridge, Valley and Ridge, and Appalachian Plateau. The land is generally hilly to mountainous with frequent rock outcroppings in upper areas of the Basin. From Harpers Ferry to the outskirts of Washington, the land is open plain with scattered forest cover. West of the Blue Ridge Province, rocks are folded sedimentary types, including limestone, dolomite, sandstone and shale, while to the east, rocks are mainly crystalline and igneous types. Sedimentary rocks and alluvium predominate from Washington to the mouth.

The Potomac River flows in a generally southeasterly direction from its headwaters on the eastern slopes of the Appalachian Mountains to the Chesapeake Bay some 400 miles away. The main stem is formed approximately 15 miles southeast of Cumberland, Maryland, by the confluence of the North and South Branches. The Potomac then flows southeasterly to the Fall Line at Great Falls, Maryland. The head of tidewater, which is also the head of actual navigation, is near the boundary line between the District of Columbia and Maryland at Little Falls, 117 miles above the Chesapeake Bay.

The major sub-basins within the Potomac River Basin, including their drainage areas, are as follows:

Sub-basin	Drainage Area (square miles)
North Branch	1,328
South Branch	1,493
Cacapon River	683
Conococheague Creek	563
Opequon Creek	345
Shenandoah River	3,054
Monocacy River	970
Antietam Creek	292

Land use in the entire Potomac Basin is estimated to be 5 percent urban, 55 percent forest, and 40 percent agricultural, including pasture lands. The basin has abundant natural resources including coal, limestone, dolomite, glass sand, clay, hard and soft woods, and granite.

The free-flowing Potomac River is approximately 280 miles long and varies in width from several feet at the headwaters to over 1,000 feet in the reach above Washington. The Potomac River's tidal portion is several hundred feet in width near its upper end at Chain Bridge and broadens to almost 6 miles at its mouth. Except for a shipping channel 24 feet deep, which extends upstream to Washington and a few short reaches with depths up to 100 feet, the tidal portion is relatively shallow with an average depth of about 18 feet. The mean tidal range is about 2.9 feet in the upper portion near Washington and about 1.4 feet near the Chesapeake Bay.

Of the 3.3 million people living in the entire basin, approximately 2.8 million reside in the Washington Metropolitan Area. The remaining area of the tidal portion, approximately 3,216 square miles, is sparsely populated. The upper basin is largely rural with a scattering of small towns having populations of 10,000 to 20,000. Farming and related industries such as canning, fruit packing, tanning, and dairy products processing are major sources of income in the region.

4. Rappahannock River Basin

The Rappahannock River Basin, comprising approximately 2,700 square miles in northeastern Virginia and extending 160 miles in a southeasterly direction from the eastern slopes of the Blue Ridge Mountains to the Chesapeake Bay, includes all of four counties--Culpepper, Madison, Rappahannock, and Richmond-- and portions of 11 counties--Caroline, Essex, Fauquier, Greene, King George, Lancaster, Middlesex, Orange, Spotsylvania, Stafford, and Westmoreland. The basin area is approximately one-seventh of the total state area of Virginia. The basin may be subdivided into three areas with boundaries based on physiographic and economic considerations.

a. Headwaters Area

The upper or headwaters area is in Rappahannock County, approximately 80 miles northwest of Fredericksburg in the Blue Ridge physiographic province where the rugged topography rises in elevation from 500 to over 3,500 feet above mean sea level. The geological formations in the mountainous regions consist of quartzites and granites, and stream channels are steep with few flood plains.

The upper or headwaters area is largely rural, with more than 84 percent of the population residing on farms or in rural residential areas. The principal industry in the region is the logging and milling of lumber. Smaller industries such as furniture and wood products, wearing apparel, metal products, and electrical equipment manufacturing are scattered throughout the area.

b. Central Area

The central area, containing the City of Fredericksburg, is the economic and population center of the Rappahannock River Basin. This area is in the Piedmont Province, a plateau lying between the eastern foot of the Blue Ridge Mountains and the Fall Line. Topography is well rounded: formations consist of mingled crystalline and metamorphic rocks, and the stream flows in a sinuous entrenched channel with limited flood plains.

Below the Fall Line at Fredericksburg, the stream meanders for about 40 miles through the flat Coastal Plain, where unconsolidated sediments of sand, gravel, and fossil shells derived from the mountainous regions to the west are laid down on a basement rock of granite. For the remaining 67 miles to the mouth, typically estuarine reaches range from 2 to 4 miles in width.

The principal industry in the Rappahannock Basin, a large cellophane manufacturing plant, is located in the central area. The major water pollution problems in the Rappahannock River are downstream from this industry. All significant waste discharges which contribute to pollution problems in the central reaches of the river originate in and around the City of Fredericksburg.

c. Lower Area

The lower basin is essentially undeveloped with approximately 95 percent of the population residing on farms or in rural residential areas.

The six incorporated towns in the region are small, the largest having a population of approximately 1,100. Industries in the lower basin having waste discharges are seasonal operations, and industrial pollution problems originating in the area are primarily local nuisances.

The river has a 12-foot minimum depth navigable channel over the entire tidal portion from the mouth to Fredericksburg, a distance of 107 miles. Twelve federally improved small boat harbors on tributaries of the lower reaches of the river are used extensively by commercial seafood boats and recreational craft.

Highly productive oyster grounds are located in the lower Rappahannock River; the reach from Towles Point upstream to Bowlers Wharf is the principal oyster growing area in the state. The estuary also serves as a spawning area for shad and striped bass.

5. York River Basin

The York River Basin, embracing approximately 2,660 square miles, lies in east central Virginia and extends about 140 miles from the divide on the Southwestern Mountains in Albemarle and Orange Counties to the Chesapeake Bay east of Yorktown.

The York River is formed in the Coastal Plain by the confluence of its two main tributaries, the Mattaponi and the Pamunkey Rivers, at West Point. From the Fall Line (vicinity of U. S. Route 360) downstream to West Point, the tributaries meander through marshes and swamps on wide flood plains. Below West Point, the main stream is relatively straight with a narrow flood plain, and numerous short streams flow directly into the reach.

The Mattaponi River, a remarkably clear stream, is formed in Caroline County by four small streams, appropriately named the Mat, the Ta, the Po and the Ni. The Pamunkey River, formed northwest of Hanover by the confluence of the North and South Anna Rivers, is frequently cloudy and heavily silted in the upper reaches by runoff from the red clay headwaters areas.

a. Mattaponi River

The Mattaponi River watershed is rural and sparsely populated with only one incorporated town (Bowling Green) in the upper watershed above West Point. Vast marshes in the downstream flood plains, essentially virgin wilderness since colonial days, have been regarded as one of the best fishing and hunting sections in Virginia. The crystal clear freshwater reaches of the Mattaponi River are abundant in bass, pike, and numerous varieties of the sunfish family; and in the spring, great numbers of shad are taken by net fishermen in the lower reaches.

The river is affected by tides and is open to navigation as far west as Aylette; however, dredging of the channel above West Point has been discontinued for several years.

b. Pamunkey River

The Pamunkey River watershed above West Point is similar to the Mattaponi River watershed with respect to its essentially rural and sparsely settled characteristics. Tides affect the lower reaches as far west as U. S. Route 360 and great flights of waterfowl and marsh birds migrate into the marsh area.

The river is not as clear in the upper reaches as the Mattaponi due to silt deposits from the red clay areas in the headwaters region; however, some of the lower tributaries are exceptionally clear.

Four incorporated towns are in the Pamunkey River watershed above West Point; the largest is Ashland with a 1960 population of 2,773.

6. James River Basin

The James River Basin, encompassing approximately 10,000 square miles, is narrow and irregular with headwaters in the Allegheny Mountains at the West Virginia State line. The James River, the most southerly major tributary stream of the Chesapeake Bay system, is approximately 400 miles in length and extends in a southeasterly direction through four physiographic provinces: Coastal Plain, Piedmont, Blue Ridge, and Ridge and Valley. There is a total fall of 988 feet from the headwaters to the Fall Line separating the Piedmont and Coastal Plain at Richmond, Virginia. Below Richmond the James is a tidal estuary that joins the Chesapeake Bay at Hampton Roads, a distance of approximately 95 miles. The mean freshwater discharge is approximately 7,500 cfs with recorded extremes of 329 and 325,000 cfs.

At Richmond, the James River flows across the Fall Line, which delineates the eastern edge of the Piedmont physiographic province, and enters the Coastal Plain. As a consequence, the James River falls approximately 75 feet in 6 miles near Richmond, and below Richmond, becomes a tidal estuary.

Above Richmond, at Bosher Dam, the Kanawha Canal diverts a portion of the James River flow to the main channel and returns it to the river at tidewater. The USGS maintains gaging stations on both the canal and the river.

The area has a mild climate, without extremes in temperature, and an adequate, well-distributed rainfall which encourages agricultutal development of the rich soil. To this date, agriculture remains a primary activity of the area.

Industry also dates back to colonial times. The forest resources provided lumber as well as charcoal for making iron from the native ore, and eventually pulp for paper making, now one of the largest industries in the State. The extensive chemical industry existing in the basin today had its beginnnings in tanning and extraction of indigo, tars, and turpentine.

a. Chickahominy River Watershed

The Chickahominy River, with headwaters in Henrico and Hanover Counties draining a water shed of approximately 400 square miles, has a mean flow near Providence Forge of 271 cfs. The river discharges into the James approximately 7 miles above Jamestown. Nearly half of Henrico County and the north side of the City of Richmond are drained by tributaries of the Chickahominy River.

Secondary waste treatment plants owned by Henrico County, private developments and Richmond's Byrd Airport provide the major waste discharges to the Chickahominy River watershed.

CHAPTER IV

WATER QUALITY CONDITIONS

Detailed analyses of the major freshwater tributary inflows to the Chesapeake Bay were conducted from June 1969 to August 1970. During this period, the following were the average measured concentrations of nutrients for the various stations:

Table IV - 1

Mean Monthly Nutrient Concentrations (mg/l)

Tributary Watershed	T PO_4 as PO_4	Pi	TKN as N	NO_2 + NO_3 as N	NH_3 as N	TOC
Susquehanna River at Conowingo, Md.	0.18	0.12	0.67	0.91	0.23	3.64
Patuxent River at Route 50 (John Hanson Highway)	2.77	1.90	1.68	1.35	1.00	7.72
Potomac River at Great Falls, Md.	0.50	0.22	0.87	1.05	0.17	6.42
Rappahannock River at Fredericksburg, Va.	0.25	0.13	0.57	0.52	0.10	4.83
Mattaponi River at Beulahville, Va.	0.16	0.13	0.58	0.11	0.07	8.08
Pamunkey River at Hanover, Va.	0.18	0.13	0.53	0.19	0.12	6.15
Chickahominy River at Providence Forge, Va.	0.57	0.39	0.73	0.25	0.07	10.53
James River at Richmond, Va.	0.20	0.13	0.64	0.66	0.13	5.51

The observed data are completely tabulated in the Appendix and illustrated in Figures IV - 1 to IV - 10. The following sections include an evaluation of this data for each tributary watershed with major emphasis placed on seasonal variations in nutrient content.

A. SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

Conowingo Reservoir, built by the Philadelphia Power & Light Company in 1928, is located nine miles above the confluence of the Susquehanna River and the Chesapeake Bay (it is approximately four miles above tidewaters).

Flow patterns within the reservoir vary from summer, normally a period of low inflow with a completely controlled outflow by the power plant, to winter with high flows and little or no flow regulation.

Generally, during the period of high flows (October through May) rapid transport through the reservoir is common with the mean residence time for water in the reservoir reported to be less than 24 hours [11].

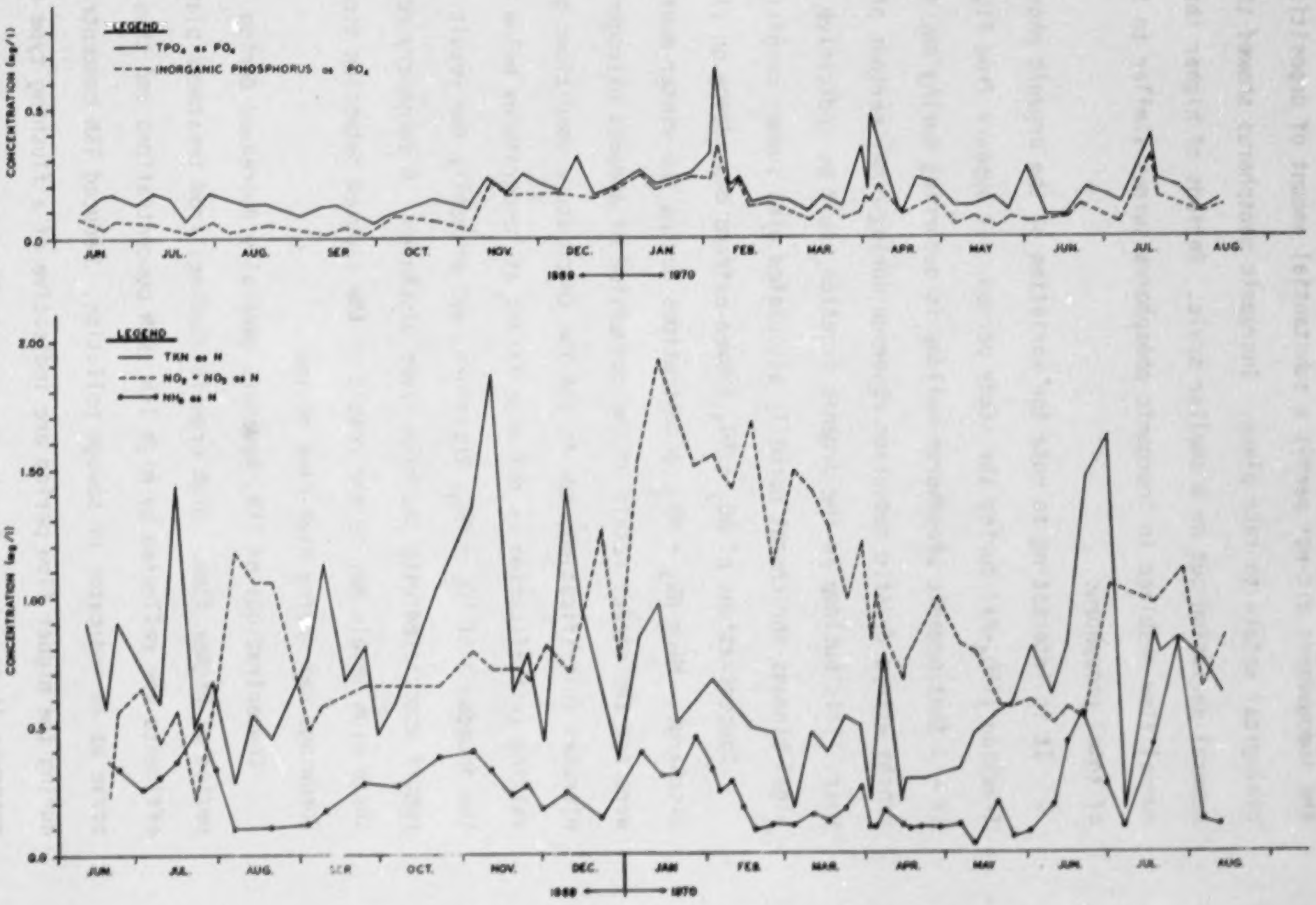
During the period of low flow extending from June through September, however, slower transport through the reservoir occurs with the mean residence time reported to be from two to six days depending on the degree of minimal flow[11].

As shown in Figure IV - 1, the period of November 1969 to May 1970 was characterized by higher total phosphorus and inorganic phosphorus concentrations in the Susquehanna River than during the remainder of the study period. Extreme variations in total phosphorus concentrations during the months of December 1969 and February, April, June and July of 1970 indicate phosphorus surges from the upper Susquehanna Basin. Since these daily surges occurred during periods of higher than normal flow, it would appear that the relatively short residence time within

NUTRIENT CONCENTRATIONS

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

(1969-1970)



the impoundment did not permit a substantial amount of deposition or biological uptake to take place. Inorganic phosphorus showed the same general variation but on a smaller scale. Periods of higher than normal flow resulted in inorganic phosphorus surges similar to those of total phosphorus.

It is interesting to note the variation of the organic phosphorus fraction (TPO_4-Pi) during the study period. It appears from Figure IV - 1 that organic phosphorus buildup is occurring during the summer months with a drastic reduction observed during other periods of the year. This buildup in the organic fraction could be indicative of algal biomass enrichment normally associated with summer conditions.

Concentrations of $NO_2 + NO_3$ showed extreme dependence on river discharge. High $NO_2 + NO_3$ concentrations during the winter months were not the direct result of the conversion of ammonia nitrogen to nitrates (nitrification) due to the low temperature conditions prevailing (nitrification is not significant at temperatures below 10°C). The abundance of $NO_2 + NO_3$, therefore, was primarily the result of land runoff associated with the high river discharge. A secondary reason for these high levels may be the result of the reduced detention time at Conowingo Dam during high-flow periods.

Concentrations of TKN, however, generally decreased during the period of higher flow. High organic loadings from treatment plant effluents are reflected by high TKN as N concentrations and thus can serve as an indicator of sewage pollution. Reduced TKN concentrations during the higher flow period are indicative of a flushing type of response in the river whereby the organic load is diluted by the high river flows. Concentrations of ammonia nitrogen remained relatively uniform, compared to these other parameters. The months of January and February 1970 did, however, show high concentrations of NH_3. In addition, ammonia nitrogen concentrations increased sharply during the months of June and July 1970.

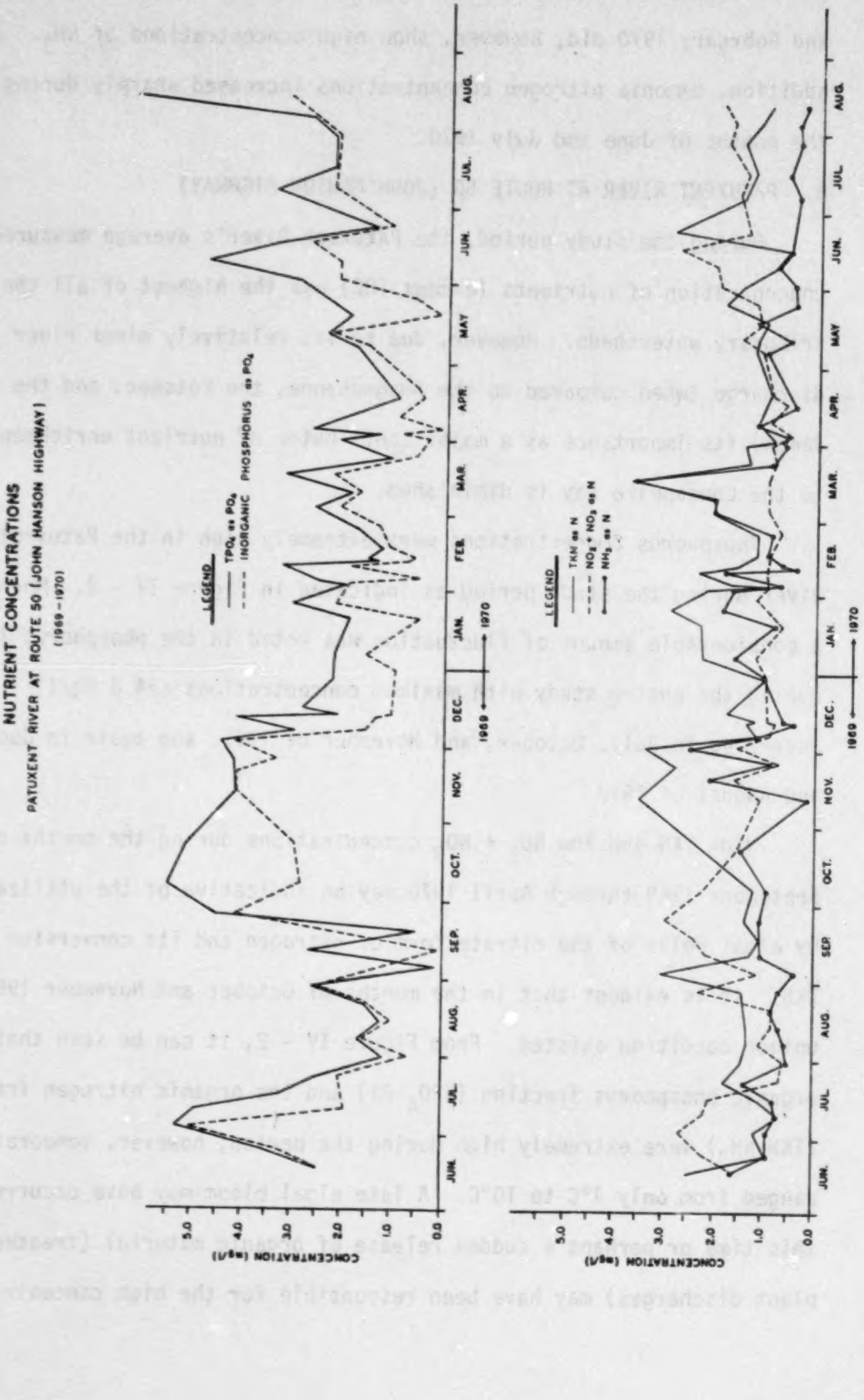
B. PATUXENT RIVER AT ROUTE 50 (JOHN HANSON HIGHWAY)

During the study period, the Patuxent River's average measured concentration of nutrients (except TOC) was the highest of all the major tributary watersheds. However, due to its relatively minor river discharge (when compared to the Susquehanna, the Potomac, and the James) its importance as a major contributor of nutrient enrichment to the Chesapeake Bay is diminished.

Phosphorus concentrations were extremely high in the Patuxent River during the study period as indicated in Figure IV - 2. Moreover, a considerable amount of fluctuation was noted in the phosphorus levels during the entire study with maximum concentrations (>4.0 mg/l) occurring in July, October, and November of 1969, and again in June and August of 1970.

High TKN and low $NO_2 + NO_3$ concentrations during the months of September 1969 through April 1970 may be indicative of the utilization by algal cells of the nitrate form of nitrogen and its conversion to TKN. It is evident that in the months of October and November 1969 a unique condition existed. From Figure IV - 2, it can be seen that the organic phosphorus fraction (TPO_4-Pi) and the organic nitrogen fraction (TKN-NH_3) were extremely high during the period; however, temperatures ranged from only 4°C to 10°C. A late algal bloom may have occurred at this time or perhaps a sudden release of organic material (treatment plant discharges) may have been responsible for the high concentrations.

IV-6



NUTRIENT CONCENTRATIONS
PATUXENT RIVER AT ROUTE 50 (JOHN HANSON HIGHWAY)
(1969-1970)

However, due to the wide variations and unstable nature of nutrient enrichment and the lack of adequate flow data during the study period, it is difficult to establish any meaningful correlations or conclusions regarding nutrient concentrations in the Patuxent River.

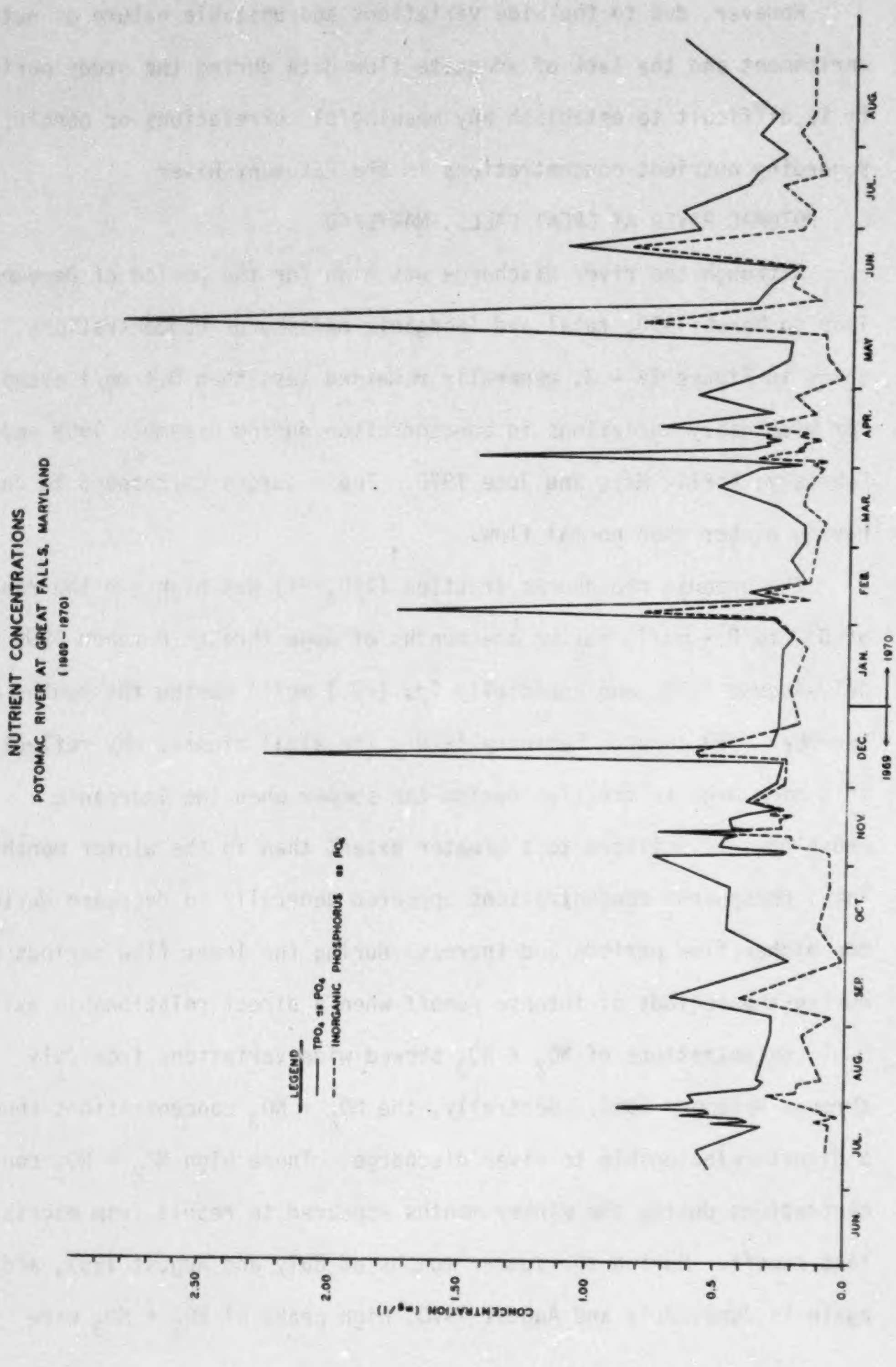
C. POTOMAC RIVER AT GREAT FALLS, MARYLAND

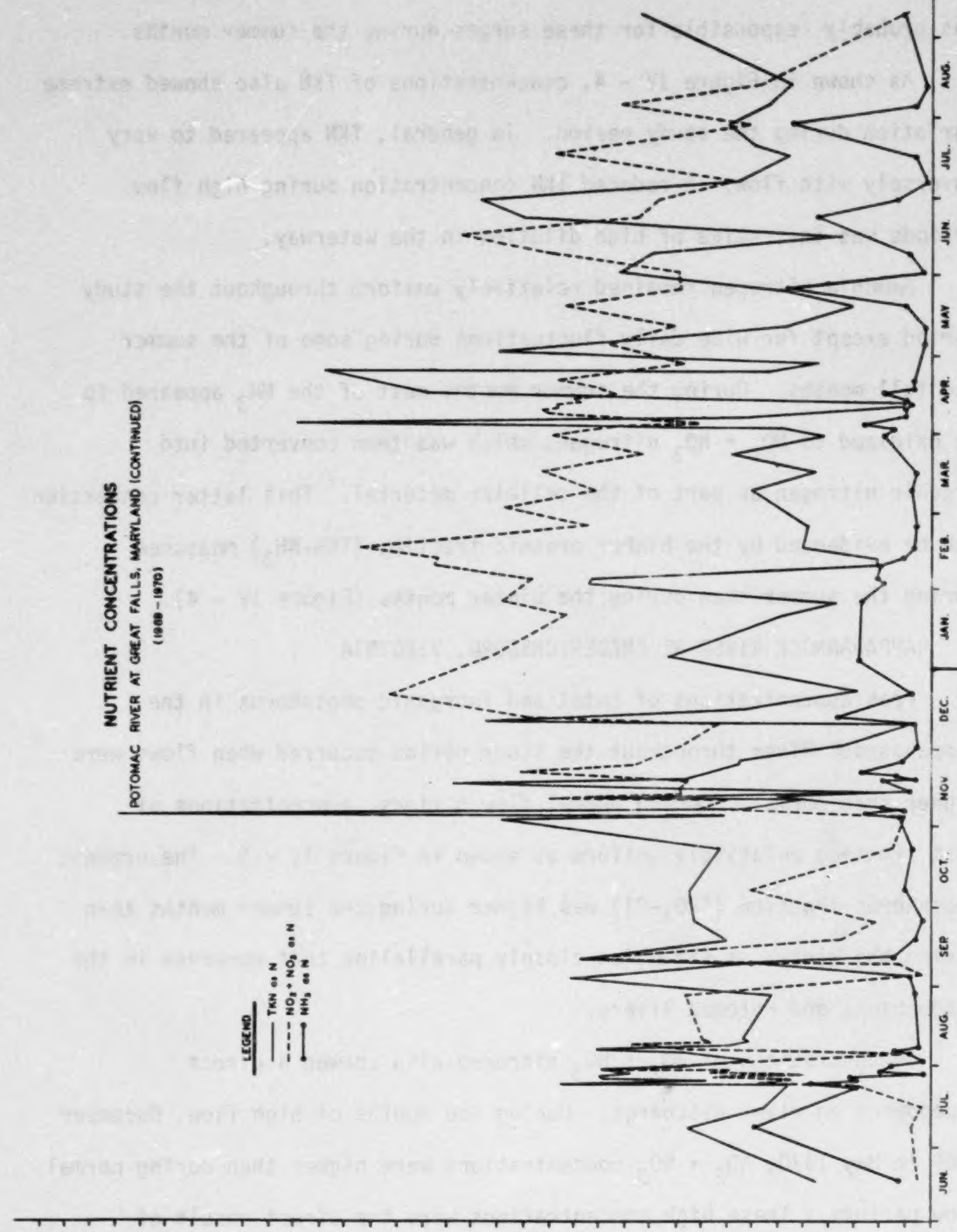
Although the river discharge was high for the period of December 1969 to March 1970, total and inorganic phosphorus concentrations, as shown in Figure IV - 3, generally remained less than 0.4 mg/l except for wide daily variations in concentration during December 1969 and February, April, May, and June 1970. These surges correspond to days having higher than normal flow.

The organic phosphorus fraction (TPO_4-Pi) was high (in the range of 0.2 to 0.5 mg/l) during the months of June through October 1969 and July-August 1970, and especially low (<0.1 mg/l) during the months of December 1969 through February 1970. The algal biomass may reflect this high organic fraction during the summer when the inorganic phosphorus is utilized to a greater extent than in the winter months. Total phosphorus concentrations appeared generally to decrease during the higher flow periods and increase during the lower flow periods except during the periods of intense runoff when a direct relationship existed.

Concentrations of NO_2 + NO_3 showed wide variations from July through November 1969. Generally, the NO_2 + NO_3 concentrations showed a direct relationship to river discharge. These high NO_2 + NO_3 concentrations during the winter months appeared to result from excessive land runoff. During the summer months of July and August 1969, and again in June, July and August 1970, high peaks of NO_2 + NO_3 were

IV-8


NUTRIENT CONCENTRATIONS
POTOMAC RIVER AT GREAT FALLS, MARYLAND
(1969-1970)
LEGEND
TPO₄ as PO₄
INORGANIC PHOSPHORUS as PO₄
CONCENTRATION (mg/l)
0.0
0.5
1.00
1.50
2.00
2.50
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUN
JUL.
AUG.
1969
1970



NUTRIENT CONCENTRATIONS
POTOMAC RIVER AT GREAT FALLS, MARYLAND (CONTINUED)
(1969-1970)

IV-4

observed. A combination of excessive river flows and nitrification was probably responsible for these surges during the summer months.

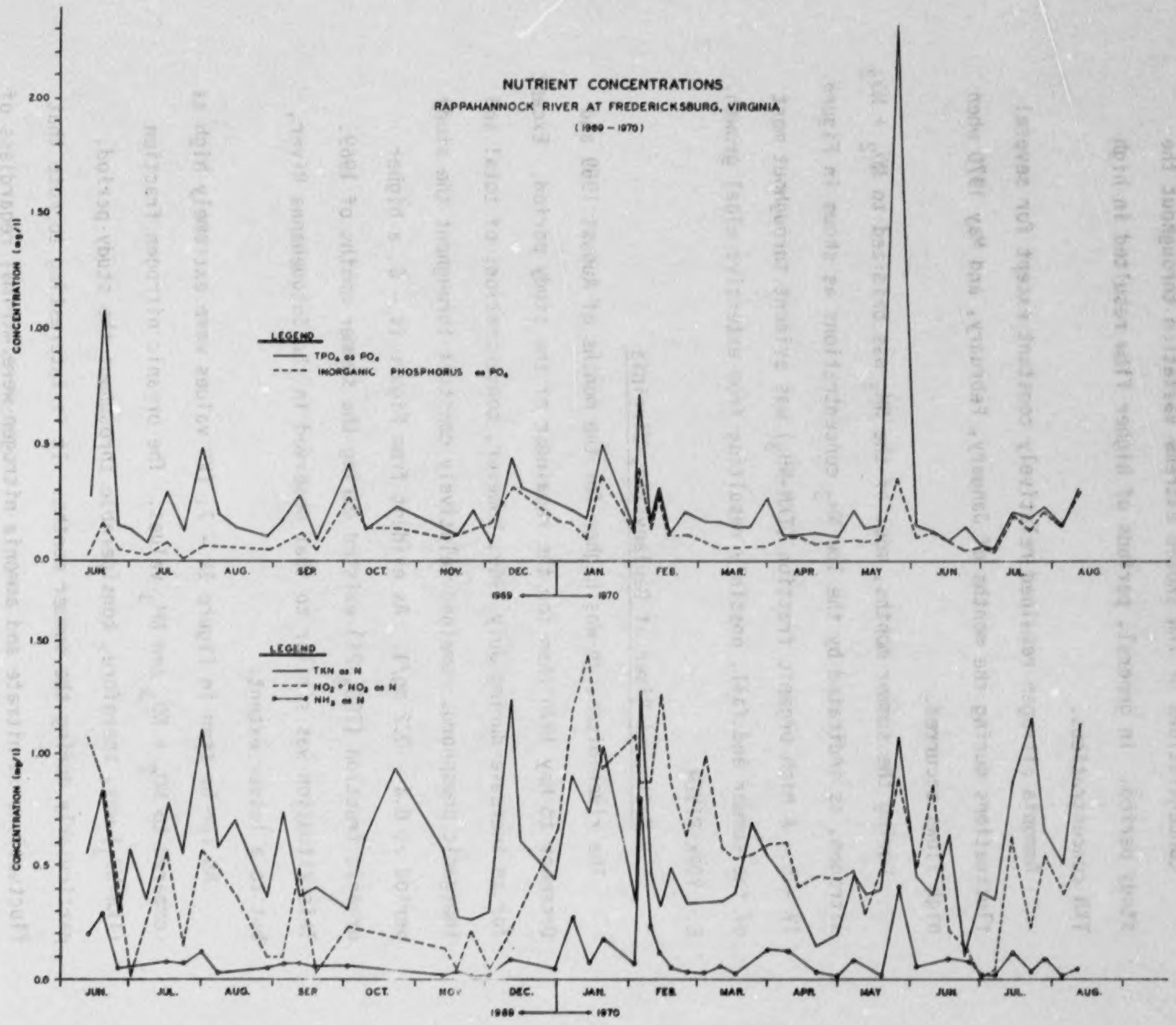
As shown in Figure IV - 4, concentrations of TKN also showed extreme variation during the study period. In general, TKN appeared to vary inversely with flow. A reduced TKN concentration during high flow periods was indicative of high dilution in the waterway.

Ammonia nitrogen remained relatively uniform throughout the study period except for wide daily fluctuations during some of the summer and fall months. During the summer months most of the NH_3 appeared to be oxidized to $NO_2 + NO_3$ nitrogen, which was then converted into organic nitrogen as part of the cellular material. This latter conversion can be evidenced by the higher organic fraction ($TKN-NH_3$) measured during the summer than during the winter months (Figure IV - 4).

D. RAPPAHANNOCK RIVER AT FREDERICKSBURG, VIRGINIA

Peak concentrations of total and inorganic phosphorus in the Rappahannock River throughout the study period occurred when flows were higher than normal. During normal flow periods, concentrations of both remained relatively uniform as shown in Figure IV - 5. The organic phosphorus fraction (TPO_4-Pi) was higher during the summer months than during the winter, a situation closely paralleling that observed in the Susquehanna and Potomac Rivers.

Concentrations of $NO_2 + NO_3$ nitrogen also showed a direct dependence on river discharge. During the months of high flow, December 1969 to May 1970, $NO_2 + NO_3$ concentrations were higher than during normal flow periods. These high concentrations were the direct result of land runoff associated with high river discharge and, to a lesser extent, nitrification.



NUTRIENT CONCENTRATIONS
RAPPAHANNOCK RIVER AT FREDERICKSBURG, VIRGINIA
(1969 – 1970)

Concentrations of TKN showed extreme variation throughout the study period. In general, periods of higher flow resulted in high TKN concentrations.

Ammonia nitrogen remained relatively constant except for several fluctuations during the months of January, February, and May 1970 when high flows occurred.

During the summer months, most of the NH_3 was oxidized to NO_2 + NO_3 nitrogen, as indicated by the low NH_3 concentrations as shown in Figure IV - 5. A high organic fraction ($TKN-NH_3$) was evident throughout most of the summer and fall, possibly resulting from extensive algal growth.

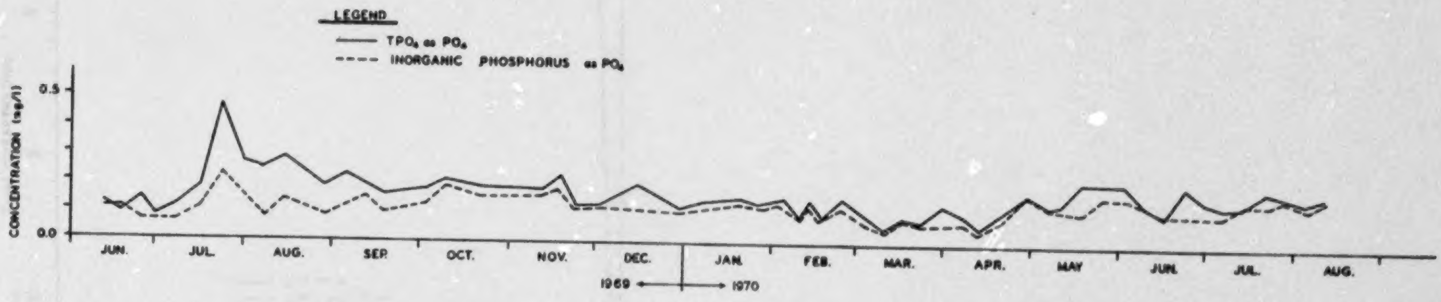
E. YORK RIVER

1. Mattaponi River at Beulahville, Virginia

The river discharge was higher for the months of August 1969 and December to May 1970 than for the remainder of the study period. Except for an increase during July 1969, however, concentrations of total and inorganic phosphorus remained relatively constant throughout the study period at 0.1 - 0.2 mg/l. As evident from Figure IV - 6, a higher organic fraction (TPO_4-Pi) existed during the summer months of 1969. This situation was similar to that observed in the Susquehanna River, but to a lesser extent.

As can be seen in Figure IV - 7, TKN values were extremely high as compared to NO_2 + NO_3 and NH_3 values. The organic nitrogen fraction ($TKN-NH_3$) was, therefore, considerable throughout the study period, particularly during the summer months. It is interesting to note that fluctuations in nitrate and ammonia nitrogen were minimal regardless of season, whereas TKN varied widely.

NUTRIENT CONCENTRATIONS
MATTAPONI RIVER AT BEULAHVILLE, VIRGINIA
(1969 - 1970)

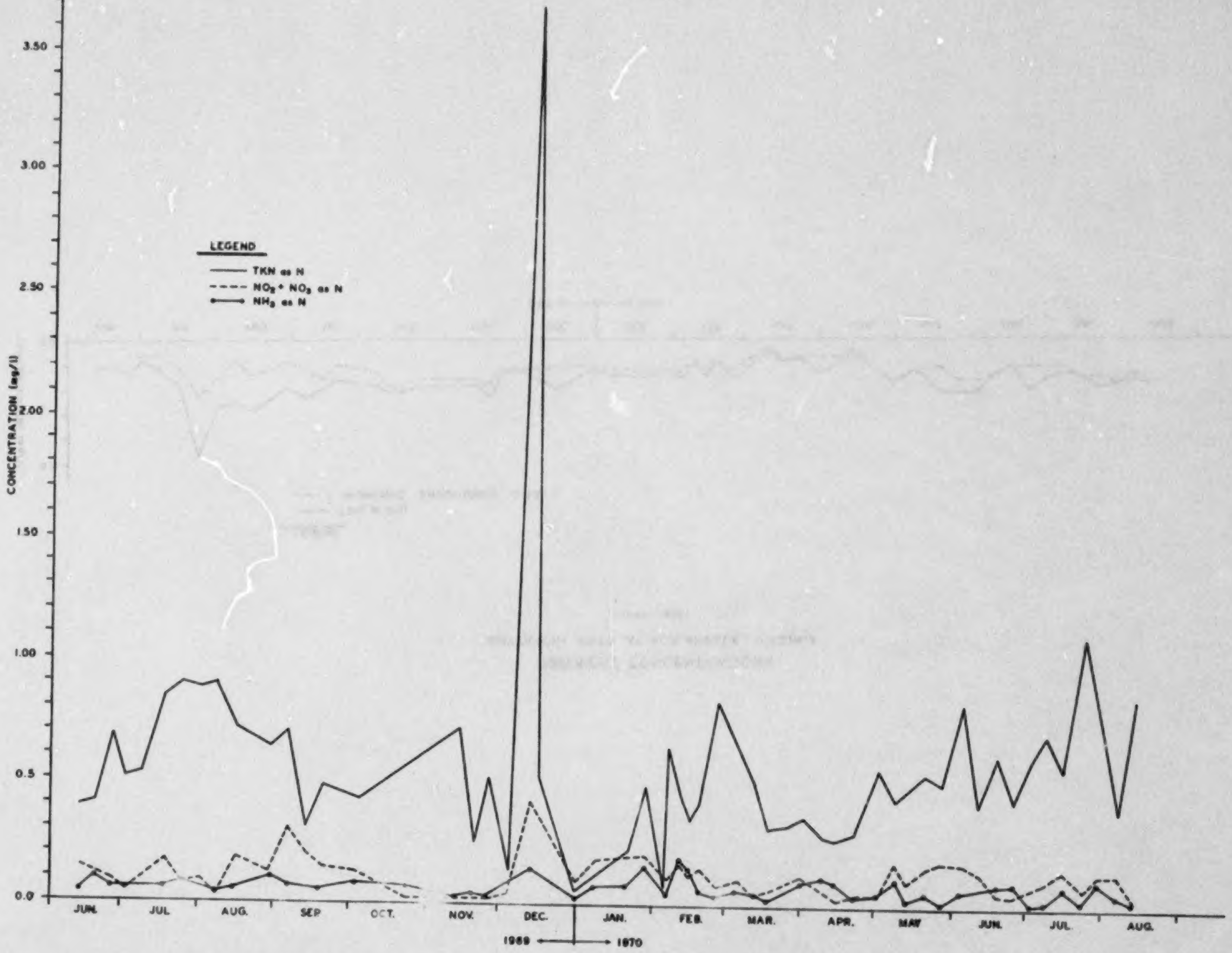


IV-14

NUTRIENT CONCENTRATIONS

MATTAPONI RIVER AT BEULAHVILLE, VIRGINIA (CONTINUED)

(1969 – 1970)



The effects of hurricane Camille on the watersheds of the Rappahannock, the Pamunkey, the Mattaponi, the James and the Chickahominy are evident from Figures V - 26 and V - 27. The tropical storm Camille caused extremely high flows for the month of August 1969; however, Figures IV - 6 and IV - 7 show that nutrient concentrations were not greatly affected.

2. Pamunkey River at Hanover, Virginia

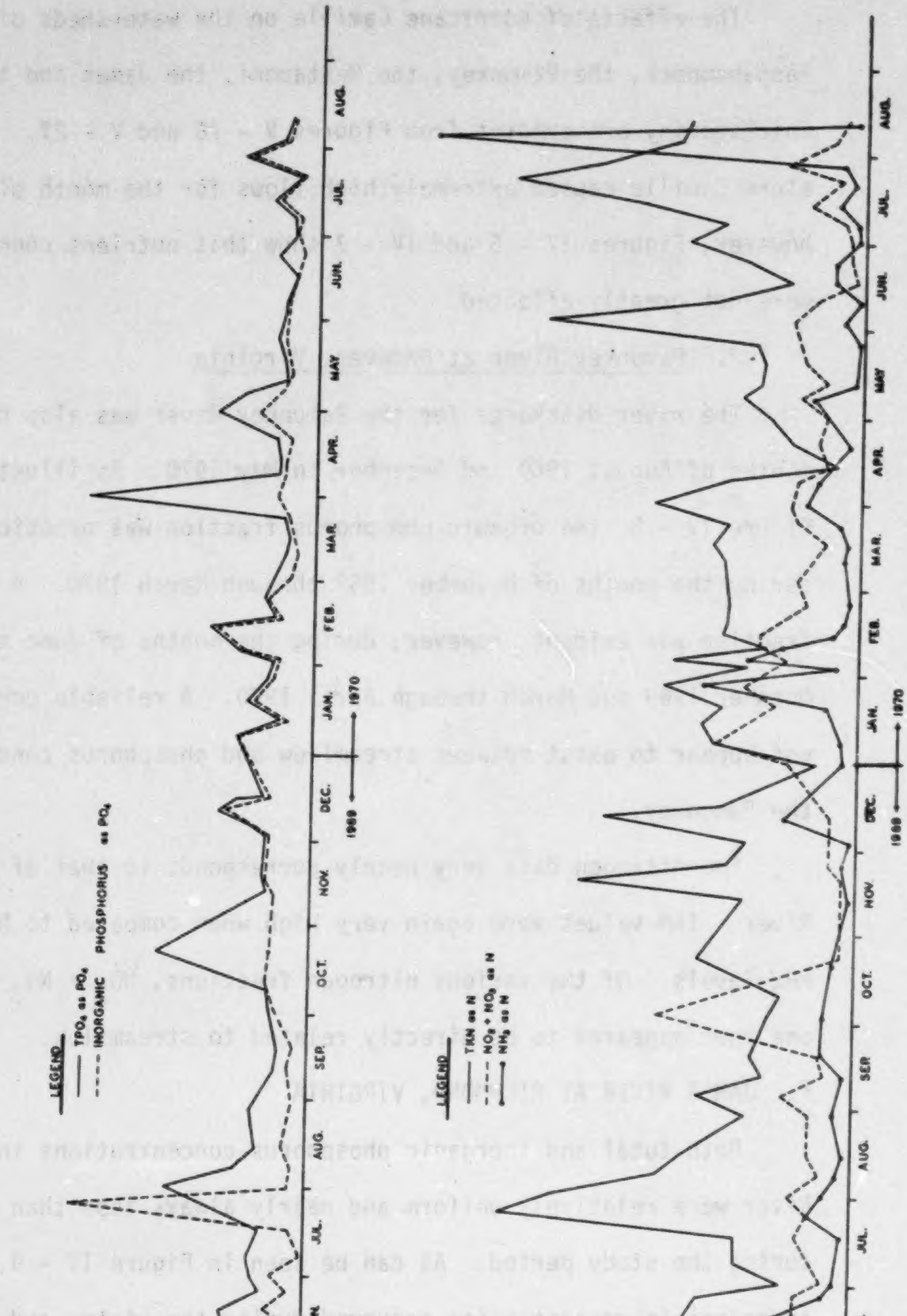
The river discharge for the Pamunkey River was also high for the months of August 1969 and December to May 1970. As illustrated in Figure IV - 8, the organic phosphorus fraction was practically absent during the months of November 1969 through March 1970. A larger organic fraction was evident, however, during the months of June through October 1969 and March through April 1970. A reliable correlation does not appear to exist between streamflow and phosphorus concentration in the Pamunkey.

The nitrogen data very nearly corresponds to that of the Mattaponi River. TKN values were again very high when compared to $NO_2 + NO_3$ and NH_3 levels. Of the various nitrogen fractions, $NO_2 + NO_3$ was the only one that appeared to be directly related to streamflow.

F. JAMES RIVER AT RICHMOND, VIRGINIA

Both total and inorganic phosphorus concentrations in the James River were relatively uniform and nearly always less than 0.4 mg/l during the study period. As can be seen in Figure IV - 9, slight increases in concentration occurred during the winter and spring months when river flows were substantially higher. The organic fraction was more pronounced during the spring and summer periods, presumably

IV-16


NUTRIENT CONCENTRATIONS
PAMUNKEY RIVER AT HANOVER, VIRGINIA
(1969 – 1970)

because of the presence of algae.

Concentrations of $NO_2 + NO_3$ nitrogen, however, appeared to decrease during the high flow periods of January to May 1970, although considerable fluctuation throughout the study period was noted. An examination of Figure IV - 9 also reveals drastic variation in TKN levels, from 0.2 mg/l to 2.0 mg/l, with seasonal patterns not evident.

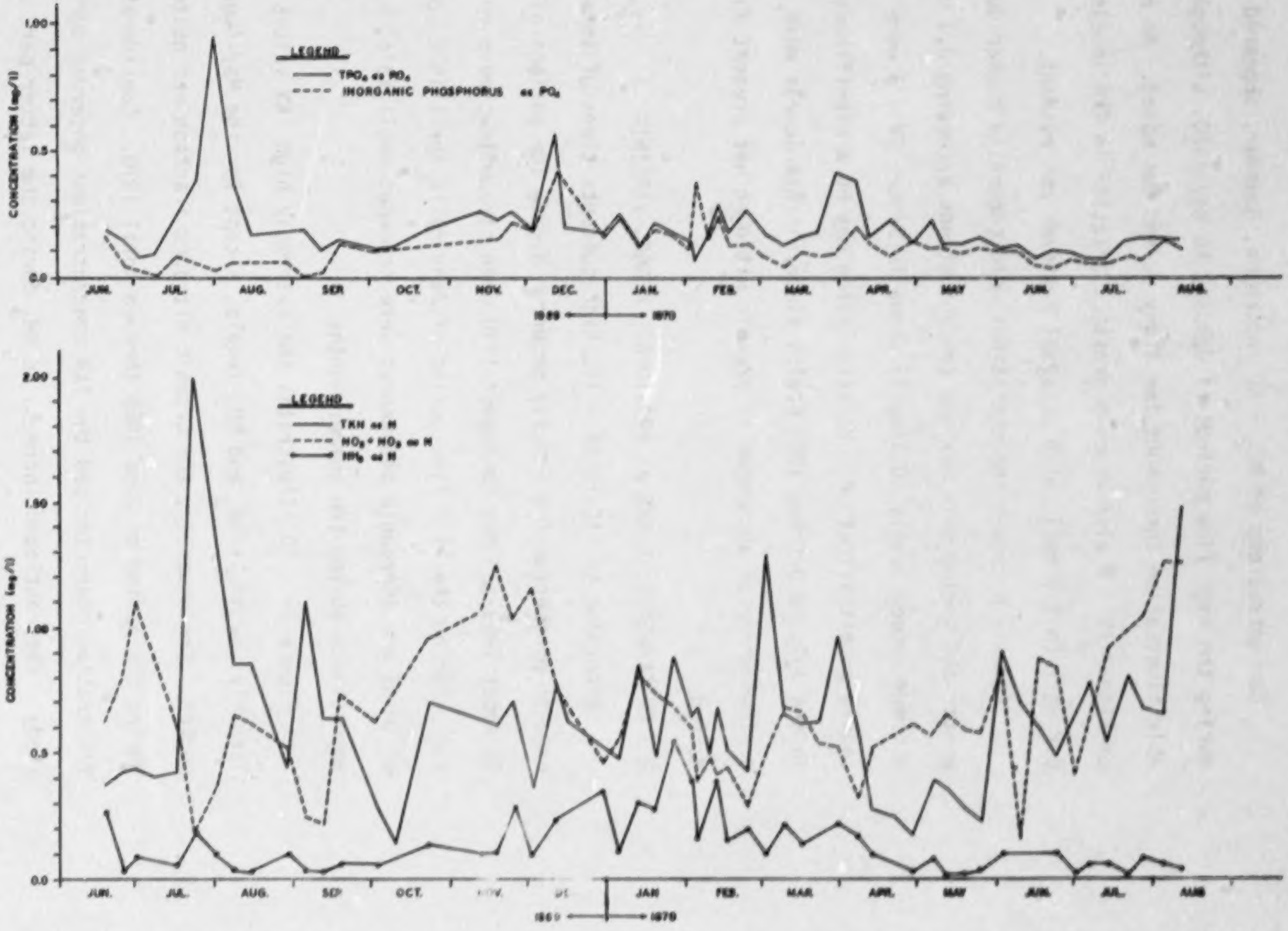
Ammonia nitrogen concentrations were generally higher during the winter and spring with maximum concentrations exceeding 0.3 mg/l. The minimum summer levels (0.1 mg/l) shown in Figure IV - 9 were probably caused by nitrification. Biostimulation may be a significant factor in the July to October 1969 period since nitrate levels were at a minimum while an abundance of organic nitrogen was present during that period.

G. CHICKAHOMINY RIVER AT PROVIDENCE FORGE, VIRGINIA

According to Figure IV - 10, high concentrations of total and inorganic phosphorus (>0.5 mg/l) occurred during the periods of July to December 1969 and May to August 1970 when streamflows were relatively low. During the high flow period of January to April 1970, concentrations of total and inorganic phosphorus were somewhat negligible, but increased appreciably during the summer months.

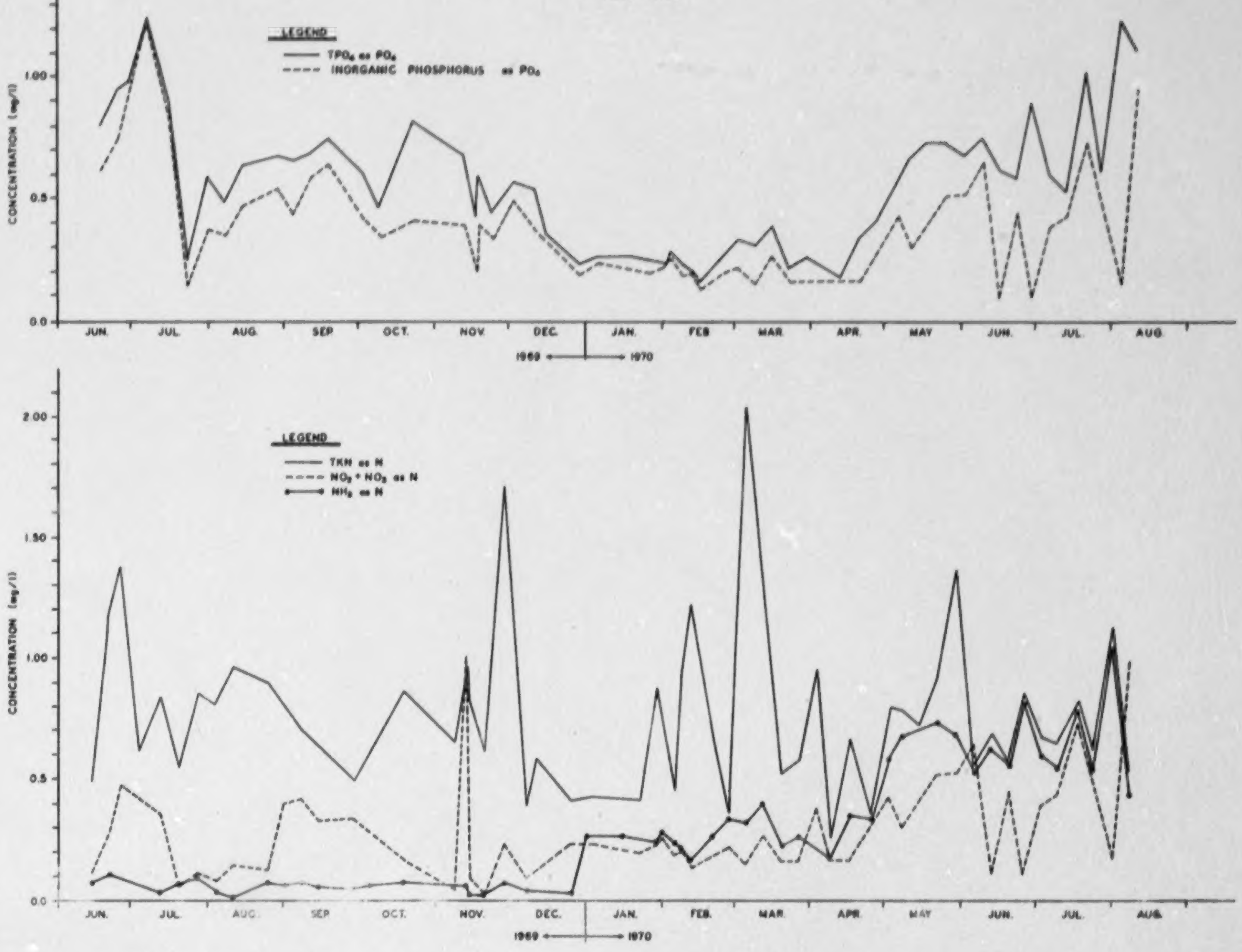
Figure IV - 10 illustrates the extremely high TKN values and relatively low $NO_2 + NO_3$ and NH_3 levels, except for the May-August 1970 period. Consequently, the organic nitrogen fraction was quite evident during the period of June 1969 through April 1970. Considerable fluctuation characterized the TKN concentrations observed during this study. The continued increase in NH_3 during the latter part of the study is particularly noteworthy.

NUTRIENT CONCENTRATIONS
JAMES RIVER AT RICHMOND, VIRGINIA
(1969–1970)



IV-19

NUTRIENT CONCENTRATIONS
CHICKAHOMINY RIVER AT PROVIDENCE FORGE, VIRGINIA
(1969 - 1970)



CHAPTER V

Nutrient Loadings and Relative Contributions

A. Delineation of Daily Nutrient Loadings (Observed)*

The daily nutrient contributions (lbs/day) from the eight major tributary watersheds for the period of June 1969 through August 1970 are illustrated in Figures V - 1 through V - 17.

For the 15-month period, the average daily nutrient contributions (lbs/day) to the Chesapeake Bay from the major tributary watersheds are as follows:

Table V - 1

Average Daily Nutrient Contributions (lbs/day)

	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
Susquehanna River at Conowingo, Maryland	59,000	34,000	130,000	230,000	42,000	576,000
Patuxent River at Route 50 (John Hanson Highway)	5,000	3,000	4,000	2,000	2,000	18,000
Potomac River at Great Falls, Md.	45,000	19,000	69,000	87,000	12,000	363,000
Rappahannock River at Fredericksburg, Va.	3,000	2,000	6,000	5,400	1,000	40,000
Mattaponi River at Beulahville, Va.	1,000	500	1,000	400	300	21,000
Pamunkey River at Hanover, Va.	1,000	1,000	3,000	1,000	600	36,000
Chickahominy River at Providence Forge, Va.	600	400	900	200	100	15,000
James River at Richmond, Va.	7,000	5,000	19,000	15,000	5,000	169,000

*Calculated from observed data: nutrient load (lbs/day) = nutrient concentration (mg/l) x river discharge (cfs) x 5.38

The seasonal nature of nutrient enrichment of the Chesapeake Bay is apparent when Figures V - 1 through V - 17 are examined in relation to the three distinct time periods of June 1969 through October 1969, November 1969 through May 1970, and June 1970 through August 1970. Estimated seasonal nutrient loadings for each tributary watershed based on observed nutrient loadings taken from these figures are presented as follows:

Table V - 2

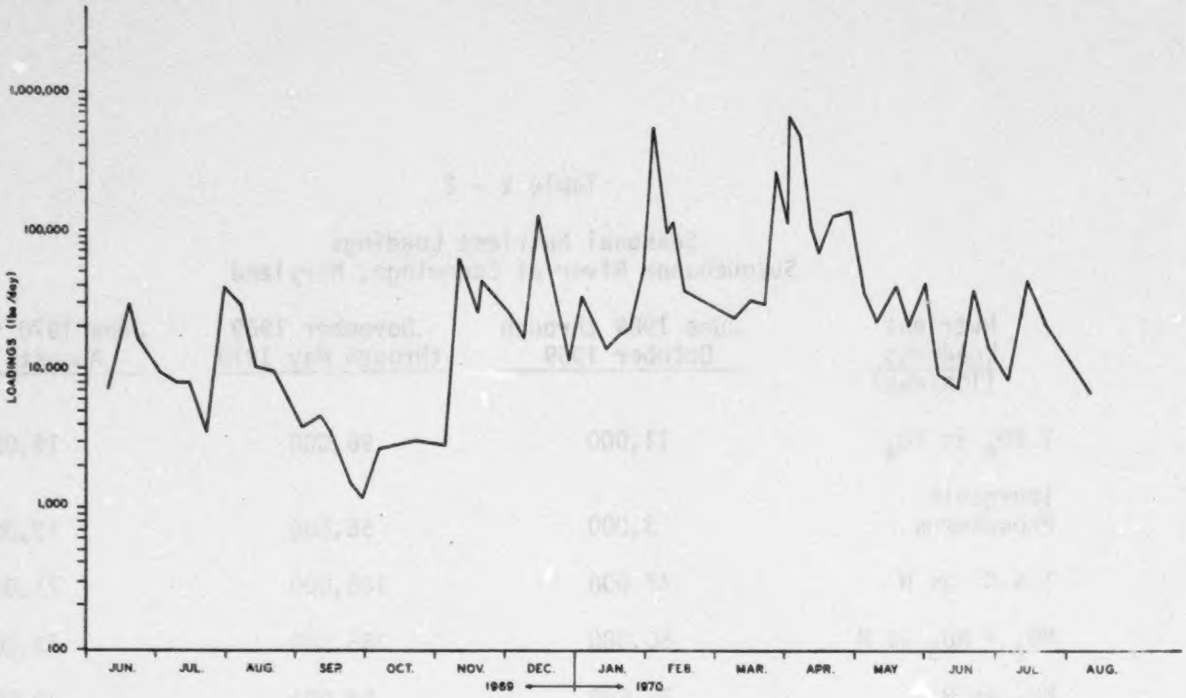
Seasonal Nutrient Loadings
Susquehanna River at Conowingo, Maryland

Nutrient Loadings (lbs/day)	June 1969 through October 1969	November 1969 through May 1970	June 1970 through August 1970
T.PO_4 as PO_4	11,000	96,000	19,000
Inorganic Phosphorus	3,000	56,000	13,000
T.K.N. as N	48,000	185,000	71,000
$NO_2 + NO_3$ as N	50,000	365,000	73,000
NH_3 as N	21,000	54,000	32,000
T.O.C.	250,000	1,000,000	490,000

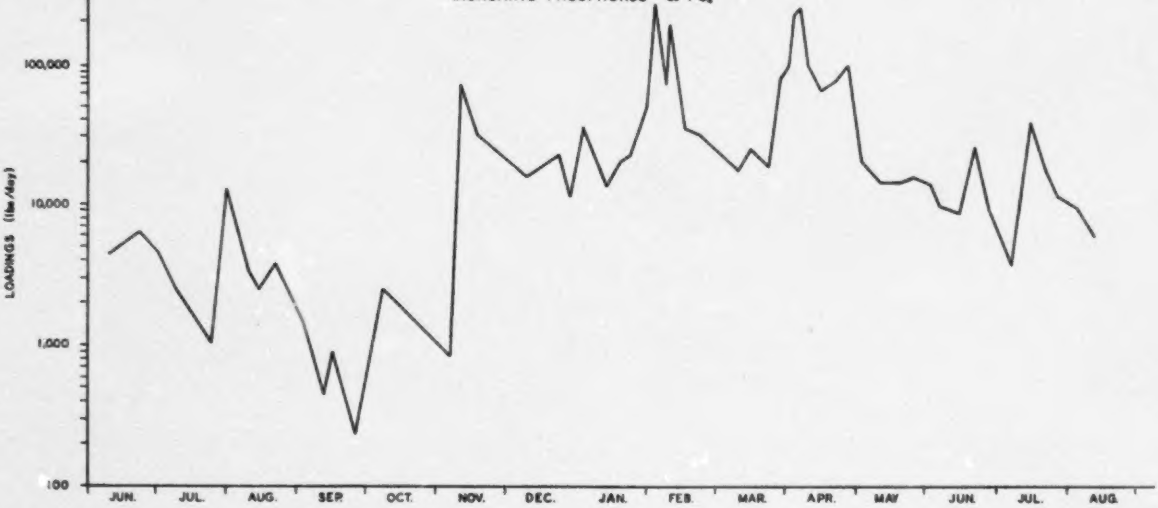
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

ACTUAL DAILY NUTRIENT LOADINGS

TPO$_4$ as PO$_4$

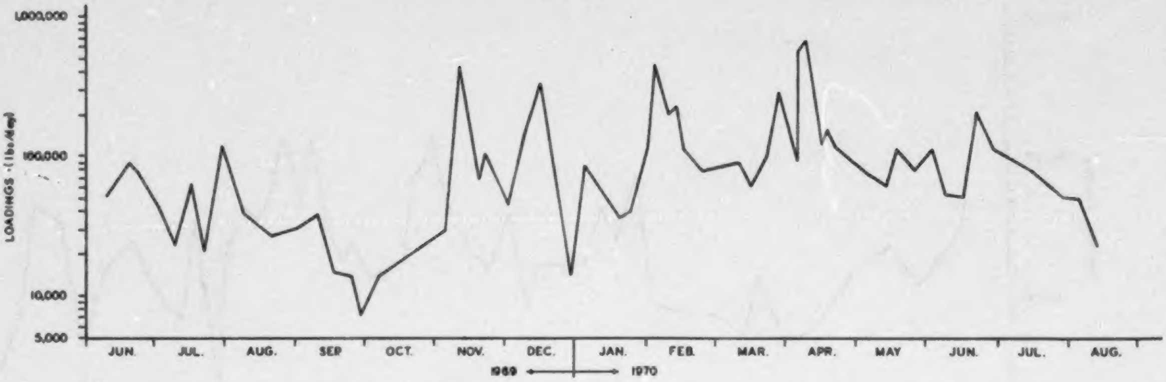


INORGANIC PHOSPHORUS as PO$_4$

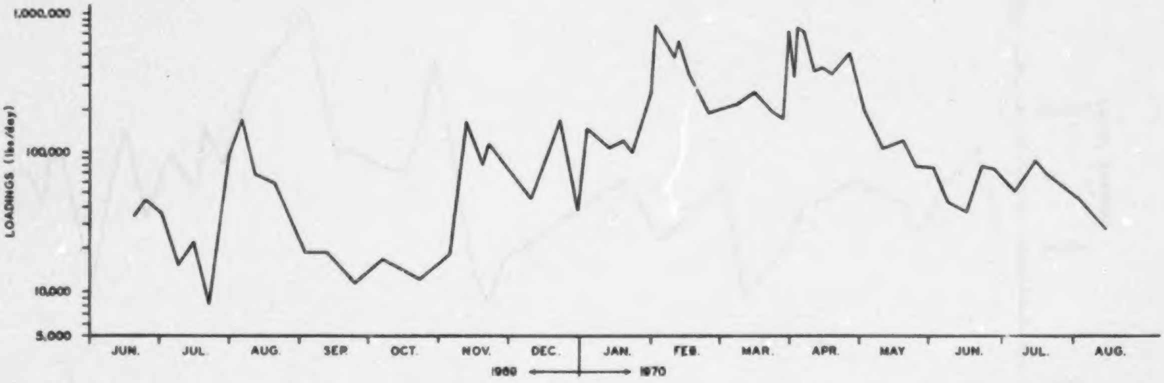


SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND
ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)

TKN as N



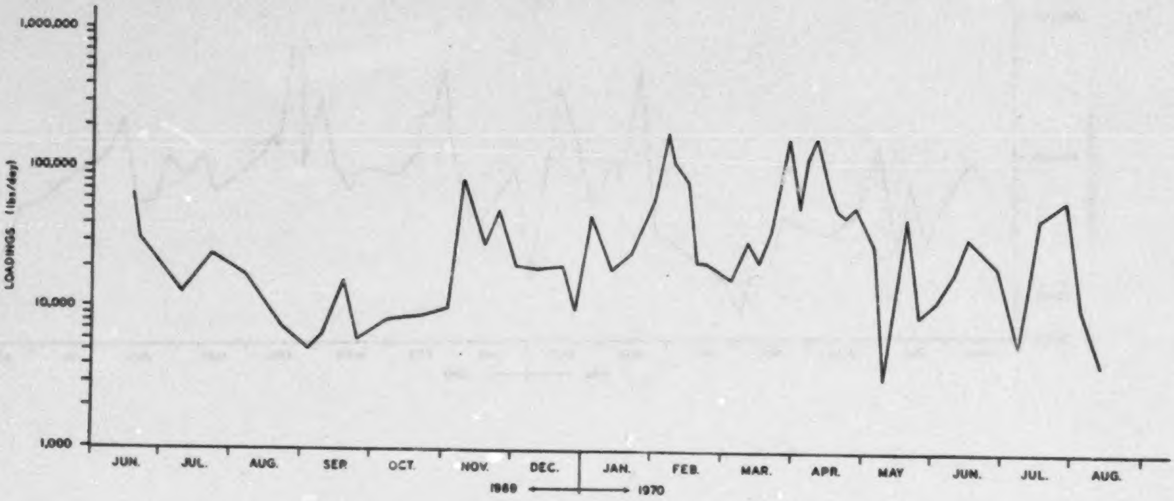
$NO_2 + NO_3$ as N



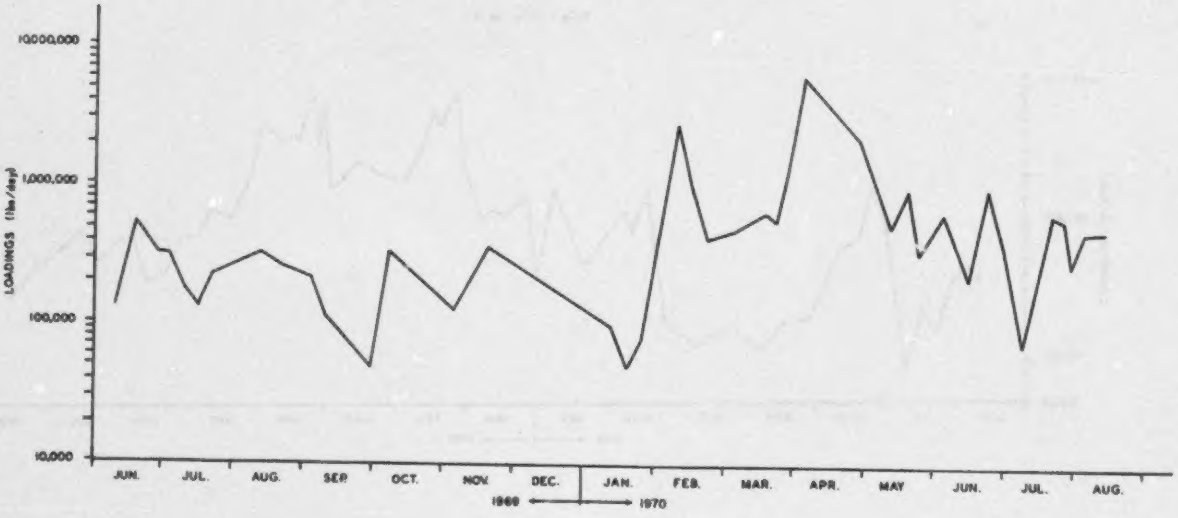
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)

NH_3 as N

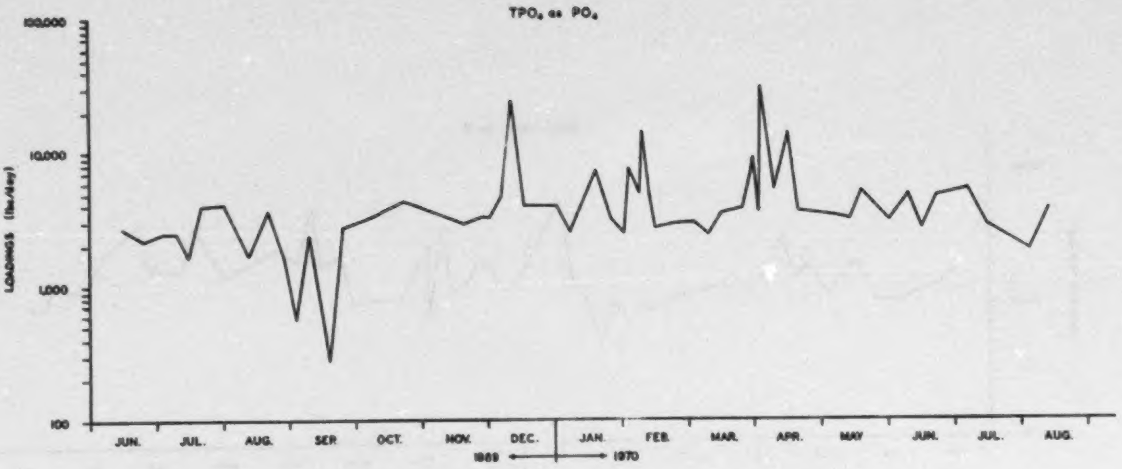


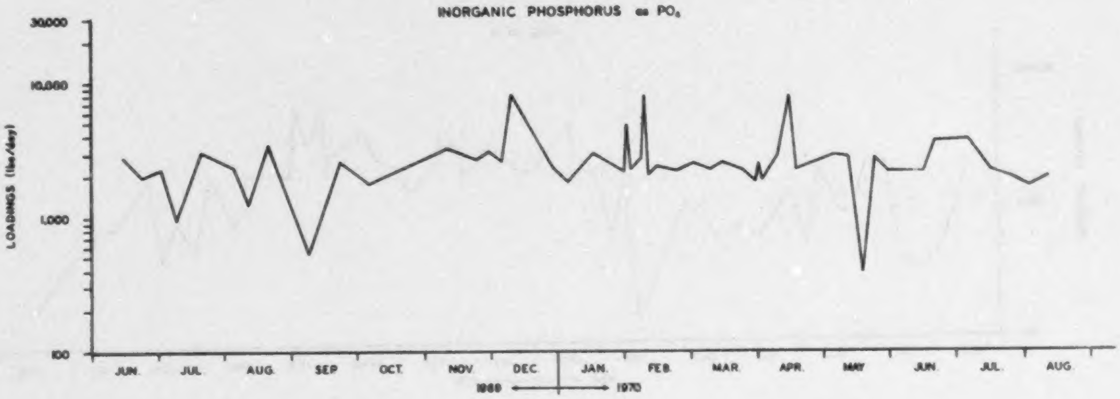
T.O.C.

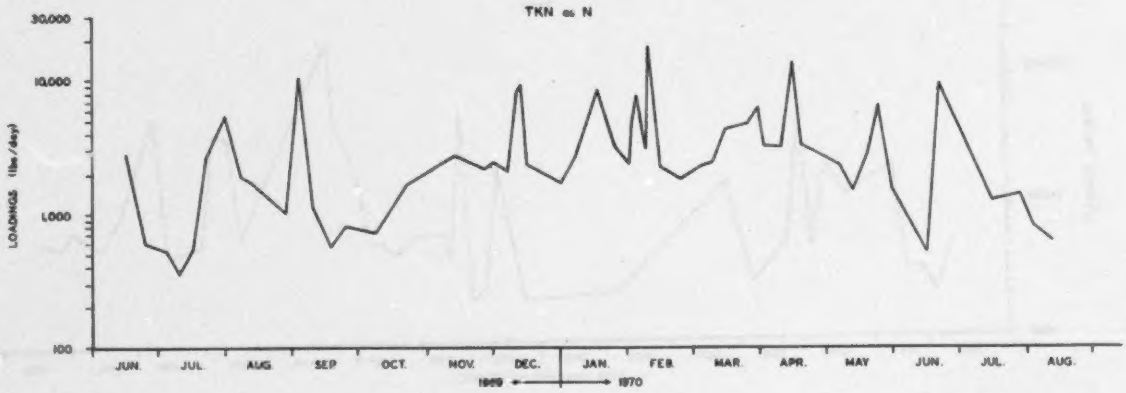


PATUXENT RIVER AT ROUTE 50 (JOHN HANSON HIGHWAY)

ACTUAL DAILY NUTRIENT LOADINGS

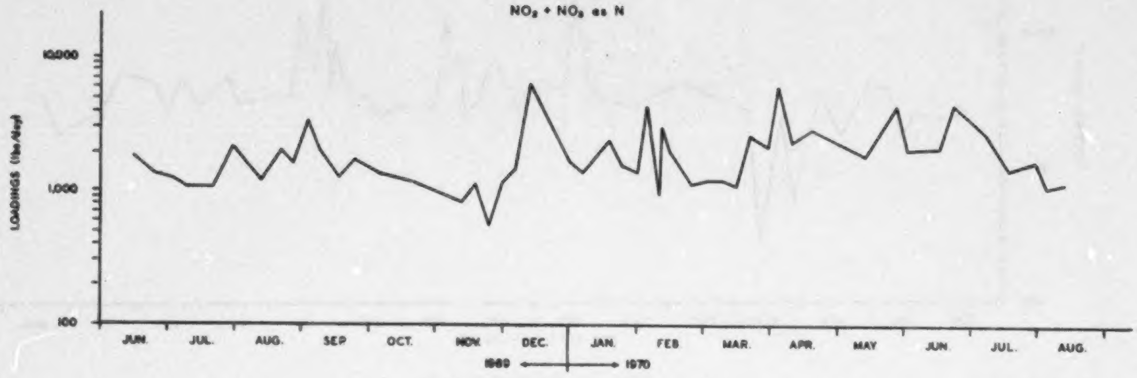

TPO$_4$ as PO$_4$

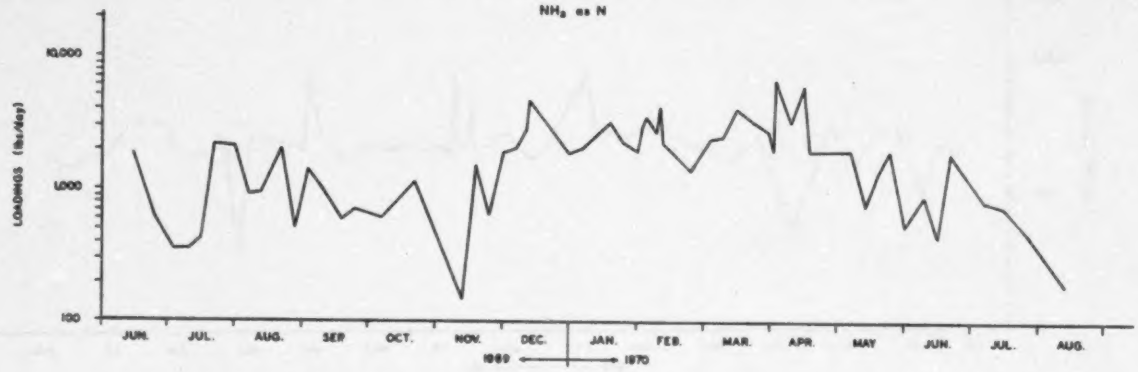

INORGANIC PHOSPHORUS as PO$_4$


TKN as N

PATUXENT RIVER AT ROUTE 50 (JOHN HANSON HIGHWAY)

ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)


$NO_2 + NO_3$ as N


NH_3 as N

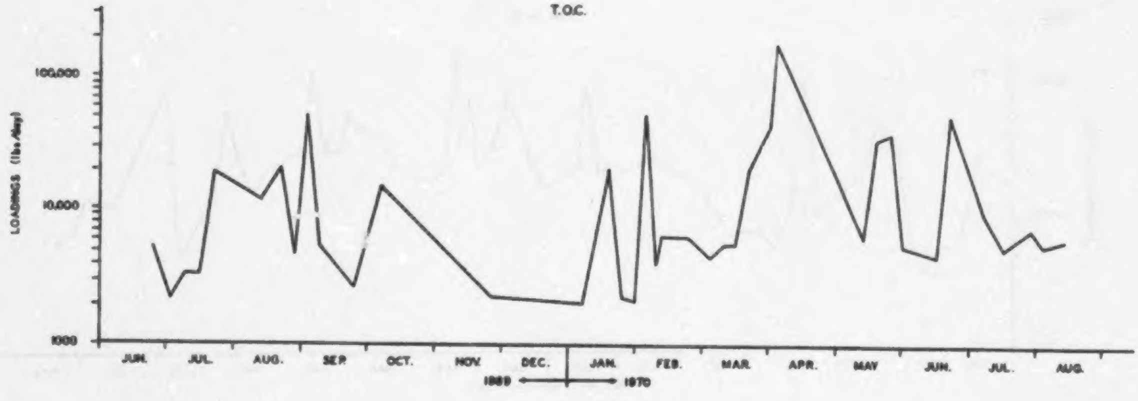

T.O.C.

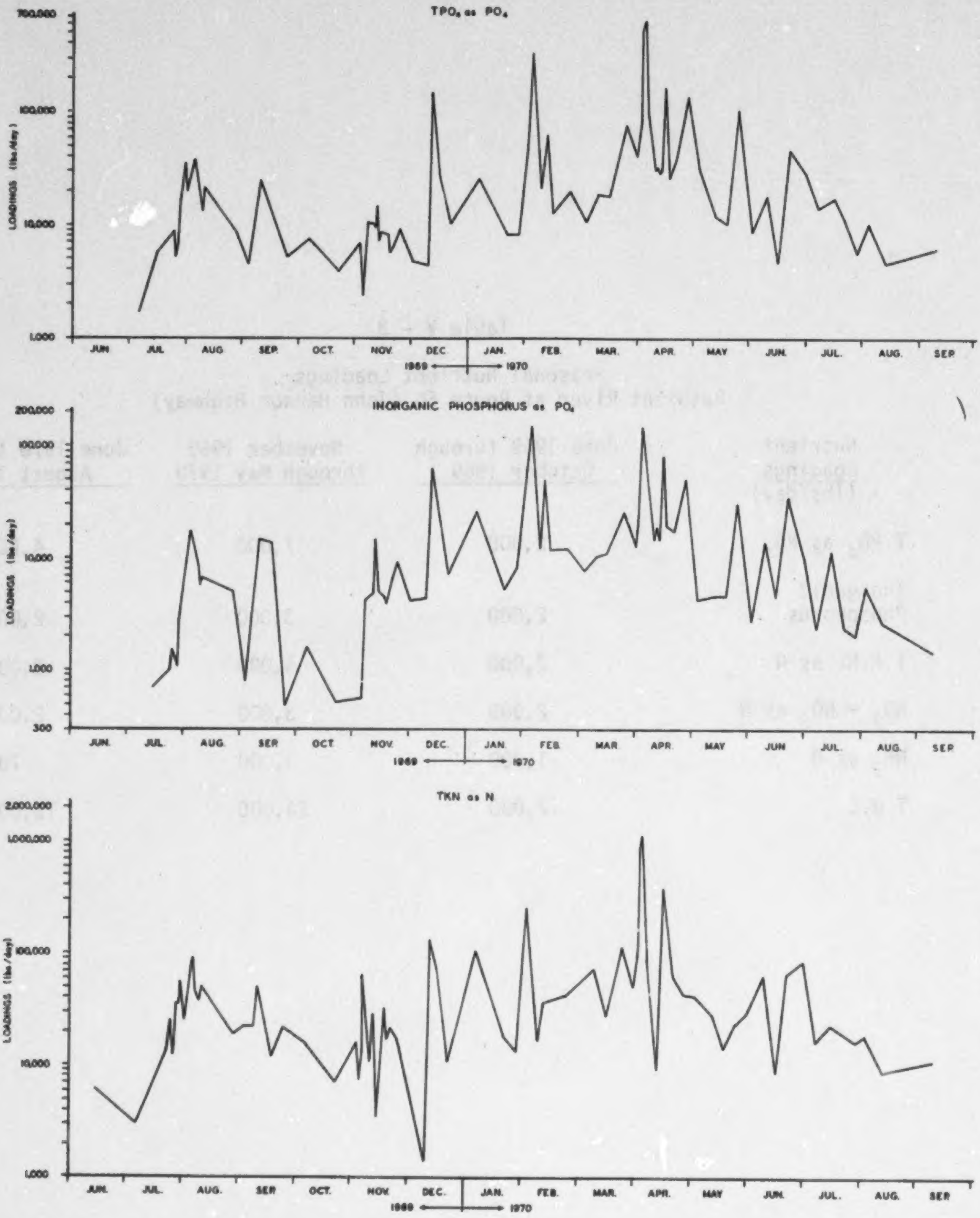
Table V - 3

Seasonal Nutrient Loadings
Patuxent River at Route 50 (John Hanson Highway)

Nutrient Loadings (lbs/day)	June 1969 through October 1969	November 1969 through May 1970	June 1970 through August 1970
T.PO_4 as PO_4	2,000	7,000	4,000
Inorganic Phosphorus	2,000	3,000	2,000
T.K.N. as N	2,000	5,000	2,000
NO_2 + NO_3 as N	2,000	3,000	2,000
NH_3 as N	1,000	3,000	700
T.O.C.	12,000	24,000	12,000

POTOMAC RIVER AT GREAT FALLS, MARYLAND

ACTUAL DAILY NUTRIENT LOADINGS



POTOMAC RIVER AT GREAT FALLS, MARYLAND

ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)

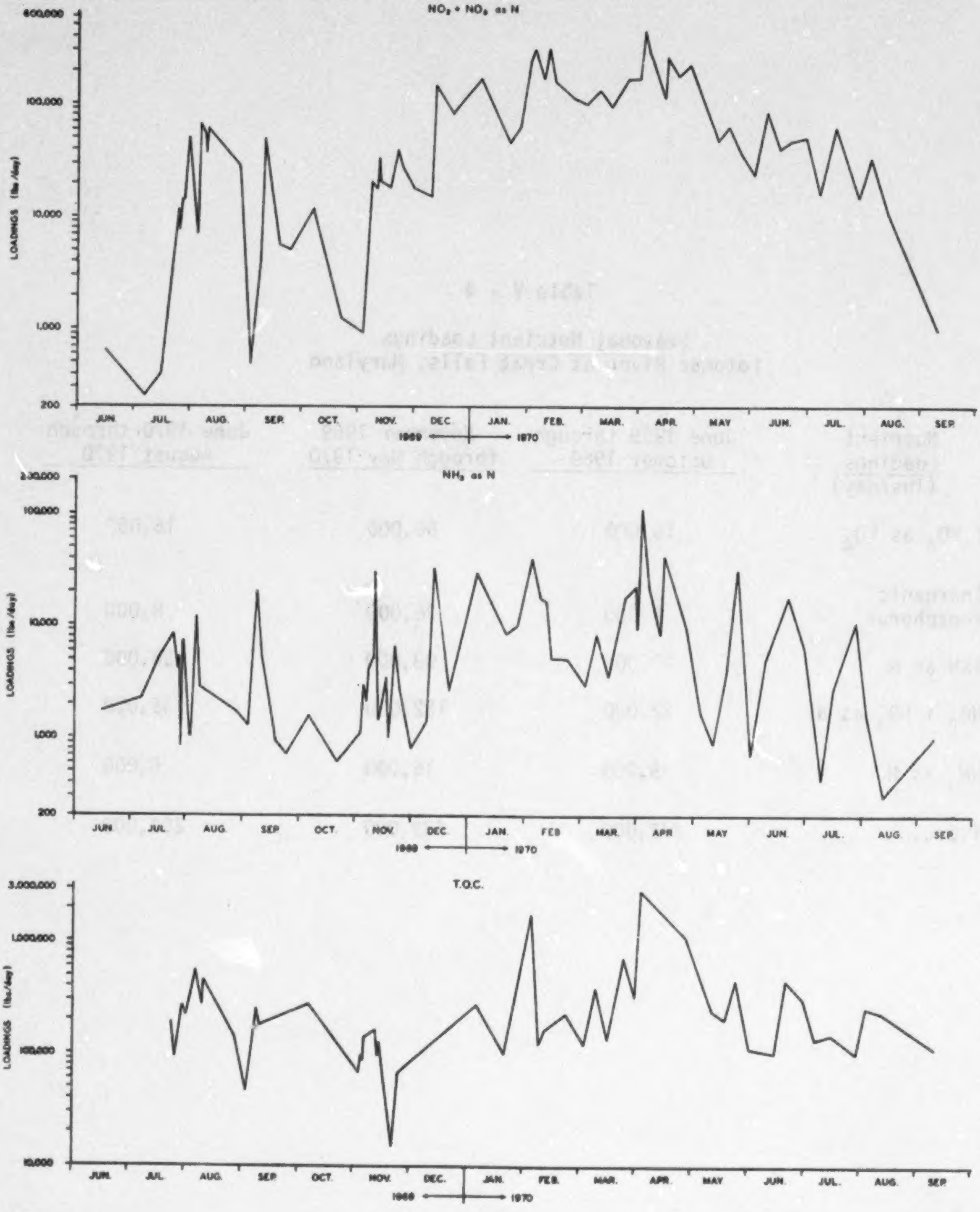


Table V - 4

Seasonal Nutrient Loadings
Potomac River at Great Falls, Maryland

Nutrient Loadings (lbs/day)	June 1969 through October 1969	November 1969 through May 1970	June 1970 through August 1970
$T.PO_4$ as PO_4	16,000	66,000	15,000
Inorganic Phosphorus	6,000	26,000	8,000
TKN as N	33,000	98,000	30,000
$NO_2 + NO_3$ as N	22,000	132,000	35,000
NH_3 as N	5,000	16,000	5,000
T.O.C.	272,000	489,000	202,000

Table V - 5

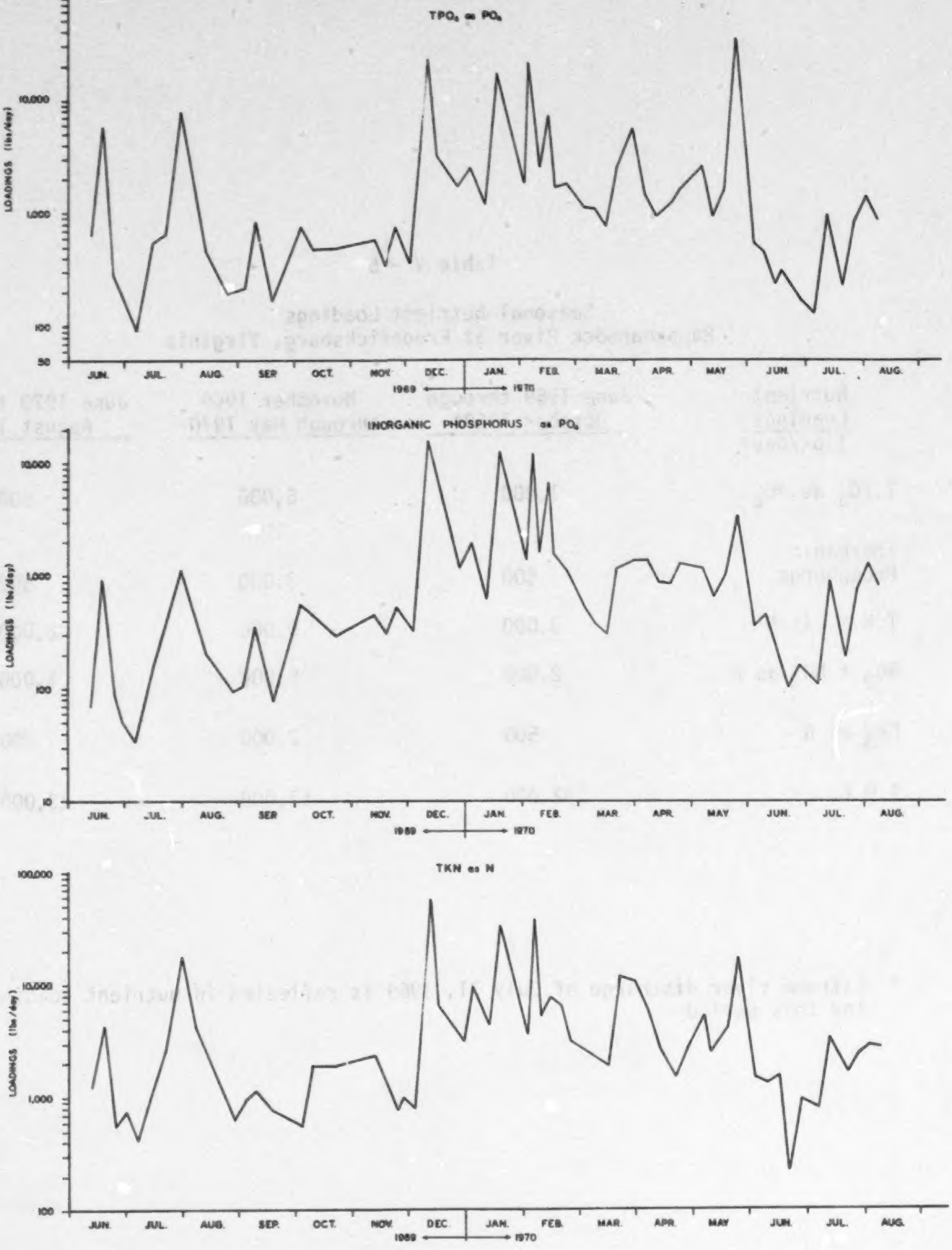
Seasonal Nutrient Loadings
Rappahannock River at Fredericksburg, Virginia

Nutrient Loadings (lbs/day)	June 1969 through October 1969*	November 1969 through May 1970	June 1970 through August 1970
T.PO_4 as PO_4	1,000	5,000	500
Inorganic Phosphorus	500	3,000	500
T.K.N. as N	3,000	9,000	2,000
$NO_2 + NO_3$ as N	2,000	9,000	1,000
NH_3 as N	500	2,000	200
T.O.C.	32,000	57,000	23,000

* Extreme river discharge of July 31, 1969 is reflected in nutrient loadings for this period

RAPPAHANNOCK RIVER AT FREDERICKSBURG, VIRGINIA

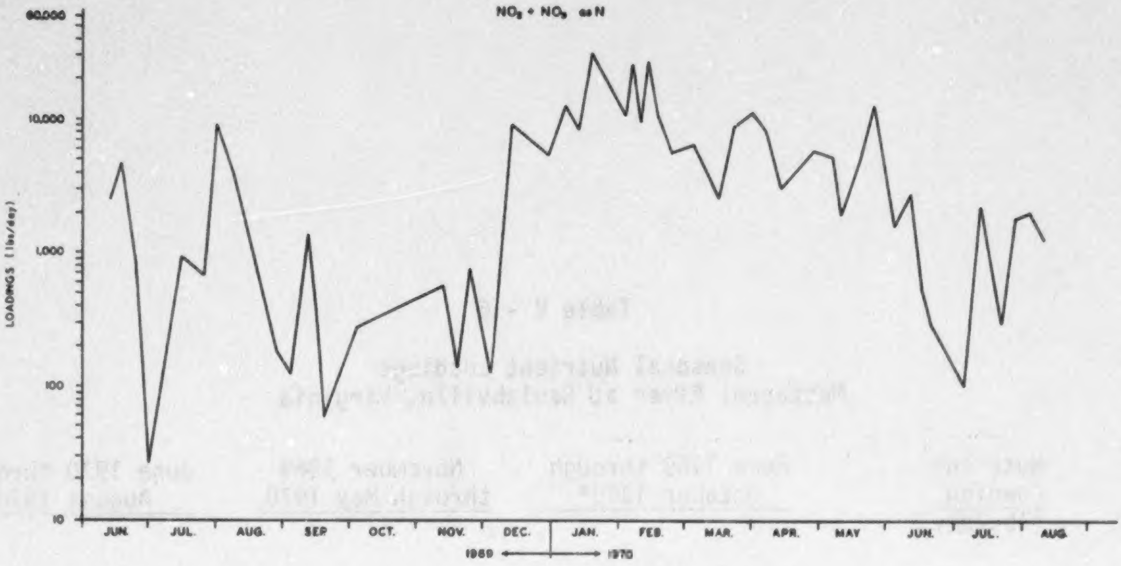
ACTUAL DAILY NUTRIENT LOADINGS

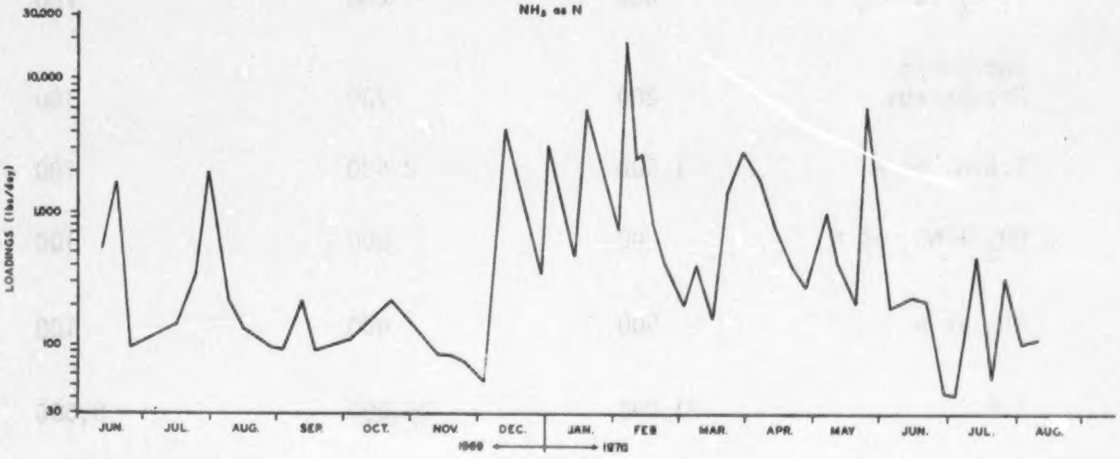


V-14

RAPPAHANNOCK RIVER AT FREDERICKSBURG, VIRGINIA

ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)





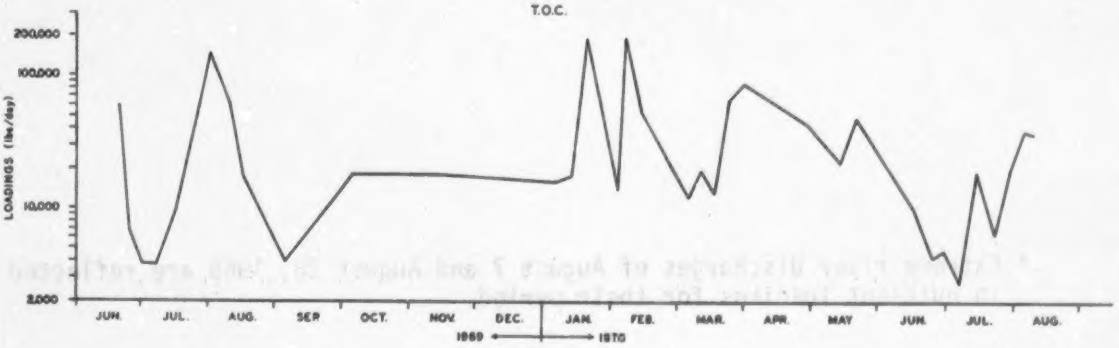


Table V - 6

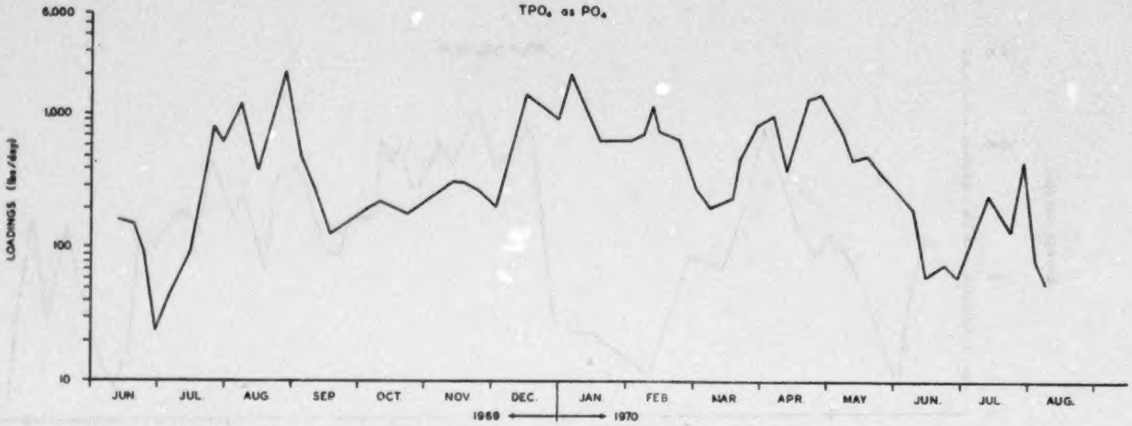
Seasonal Nutrient Loadings
Mattaponi River at Beulahville, Virginia

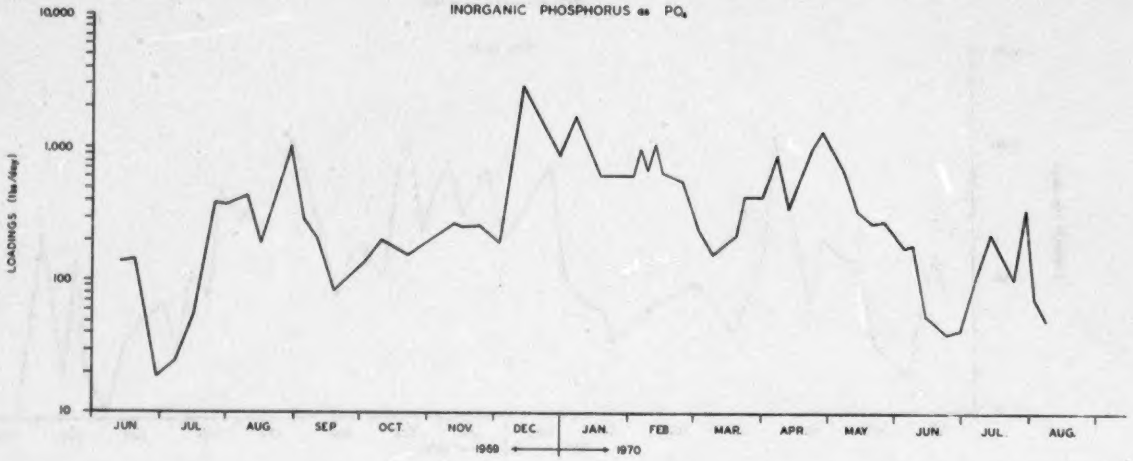
Nutrient Loading (lbs/day)	June 1969 through October 1969*	November 1969 through May 1970	June 1970 through August 1970
T.PO_4 as PO_4	400	600	200
Inorganic Phosphorus	200	700	100
T.K.N. as N	1,500	2,500	700
NO_2 + NO_3 as N	200	600	100
NH_3 as N	500	400	100
T.O.C.	23,000	25,000	8,000

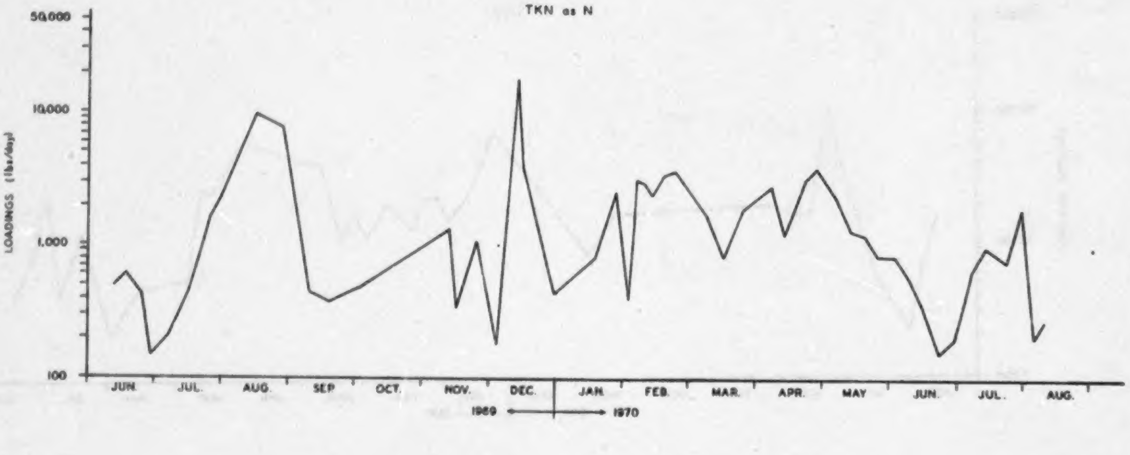
* Extreme river discharges of August 7 and August 28, 1969 are reflected in nutrient loadings for their period.

MATTAPONI RIVER AT BEULAHVILLE, VIRGINIA

ACTUAL DAILY NUTRIENT LOADINGS

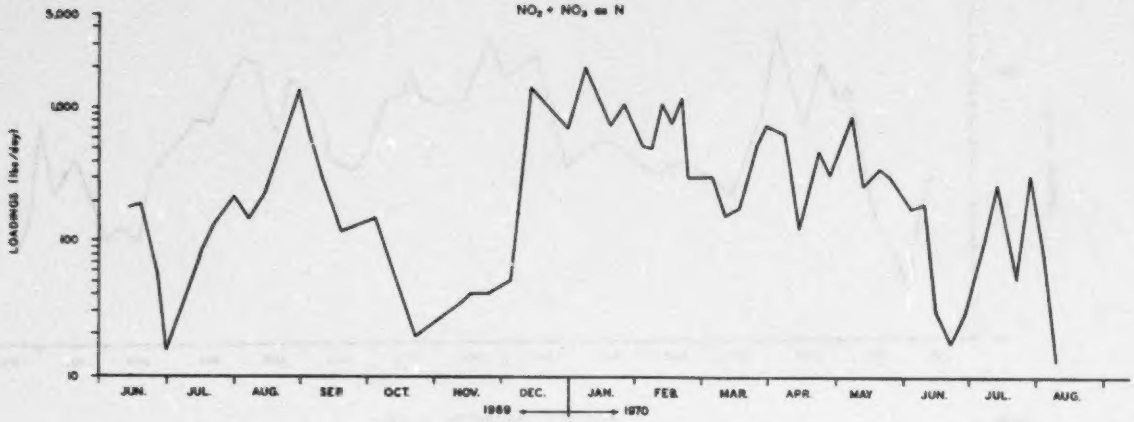




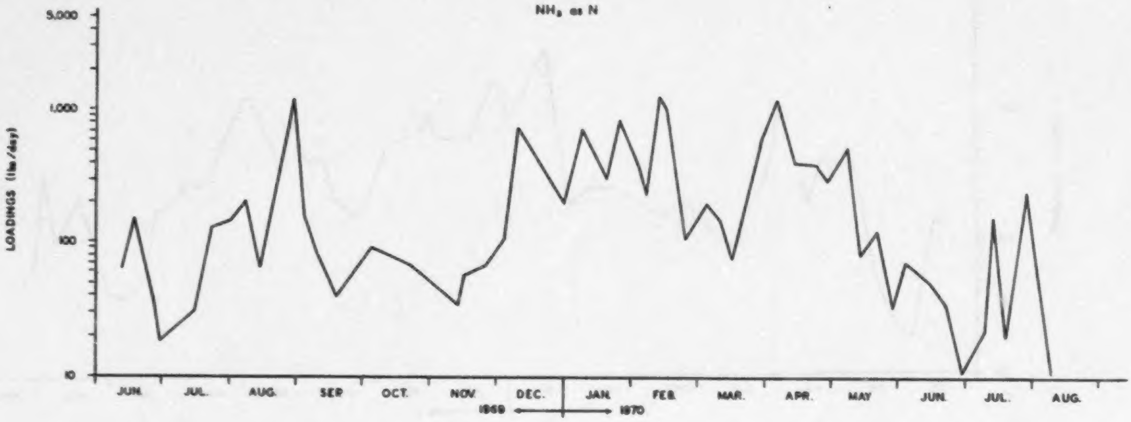


MATTAPONI RIVER AT BEULAHVILLE, VIRGINIA

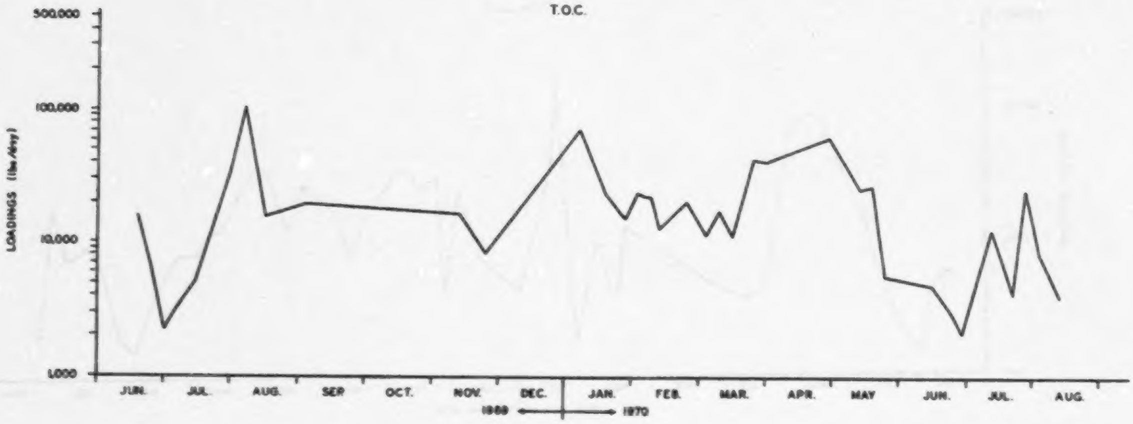
ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)



$NO_2 + NO_3$ as N



NH_3 as N



T.O.C.

V-18

Table V - 7

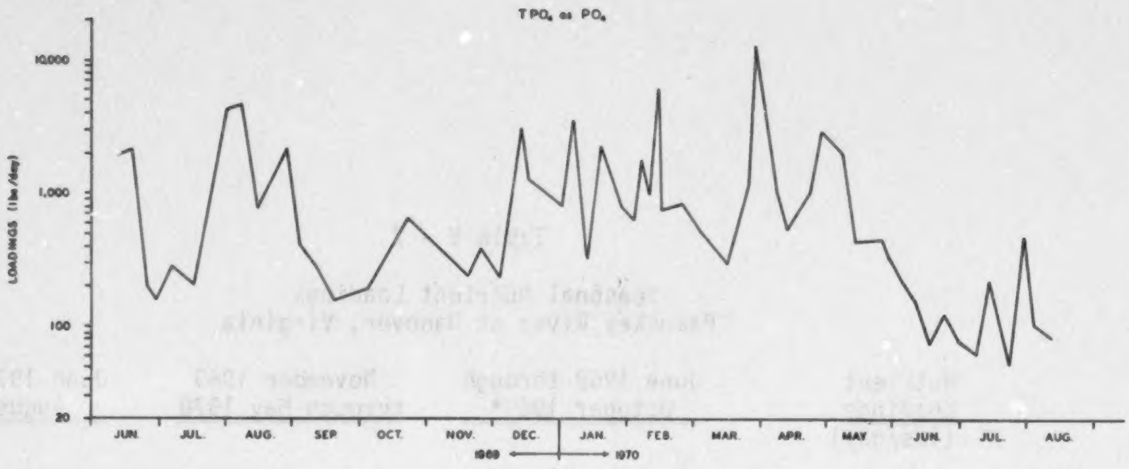
Seasonal Nutrient Loadings
Pamunkey River at Hanover, Virginia

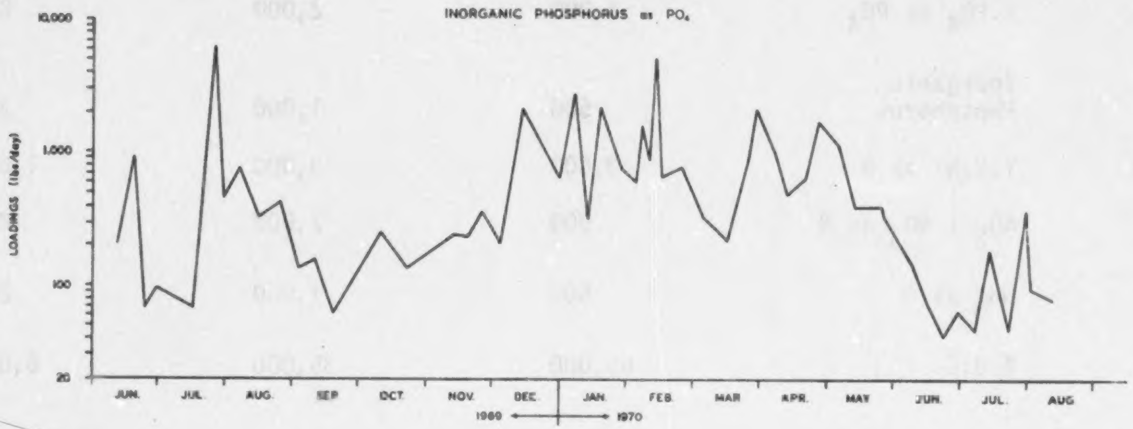
Nutrient Loadings (lbs/day)	June 1969 through October 1969*	November 1969 through May 1970	June 1970 through August 1970
T.PO_4 as PO_4	1,000	2,000	200
Inorganic Phosphorus	500	1,000	200
T.K.N. as N	3,000	3,000	1,000
NO_2 + NO_3 as N	900	2,000	200
NH_3 as N	500	1,000	200
T.O.C.	65,000	35,000	6,000

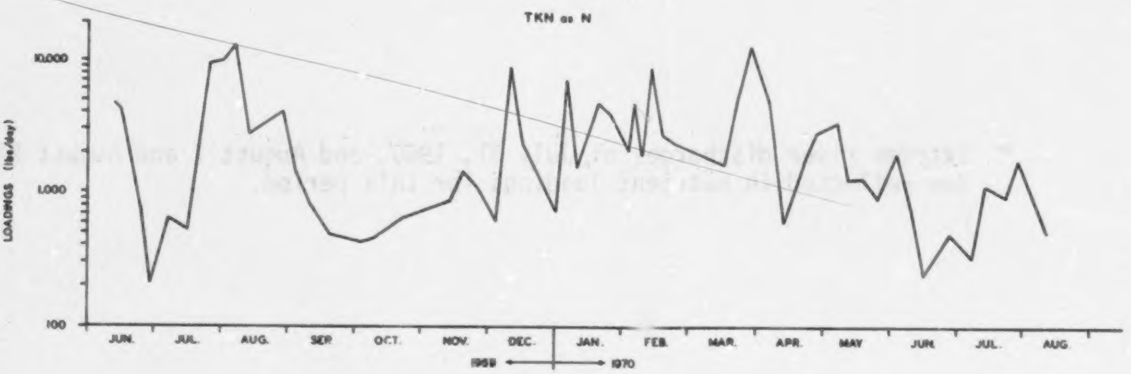
* Extreme river discharges of July 31, 1969, and August 7 and August 28, 1969 are reflected in nutrient loadings for this period.

PAMUNKEY RIVER AT HANOVER, VIRGINIA

ACTUAL DAILY NUTRIENT LOADINGS

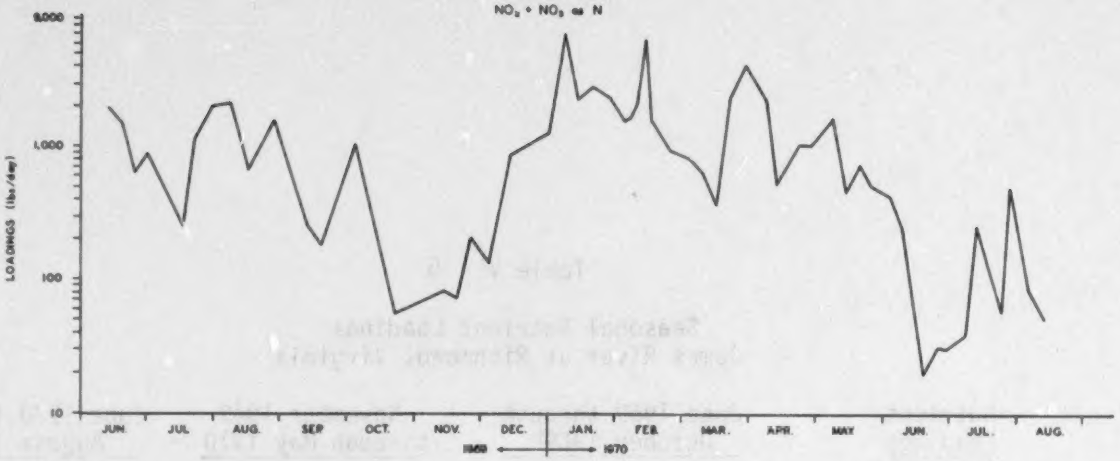


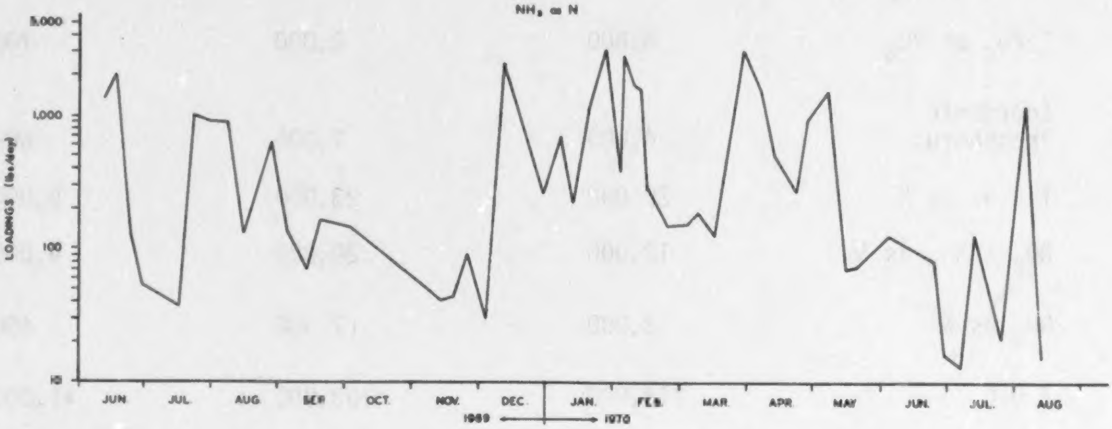




PAMUNKEY RIVER AT HANOVER, VIRGINIA

ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)





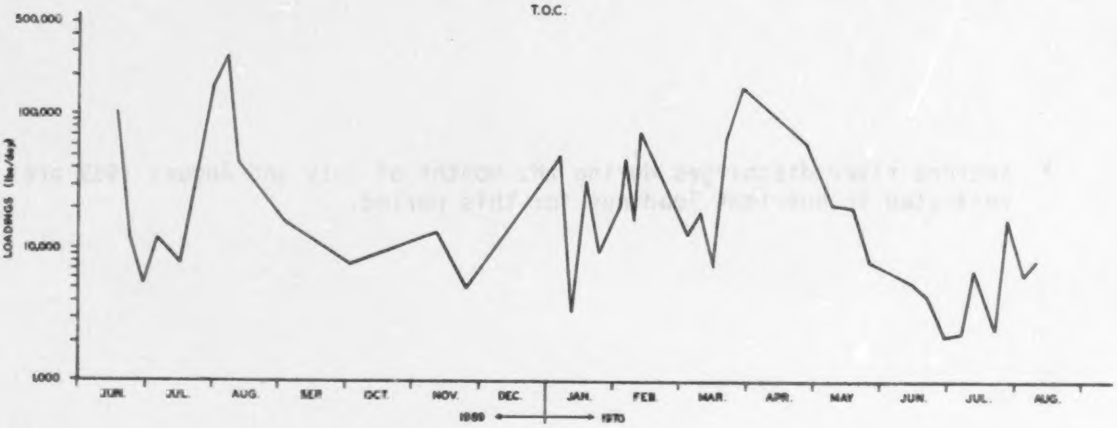


Table V - 8

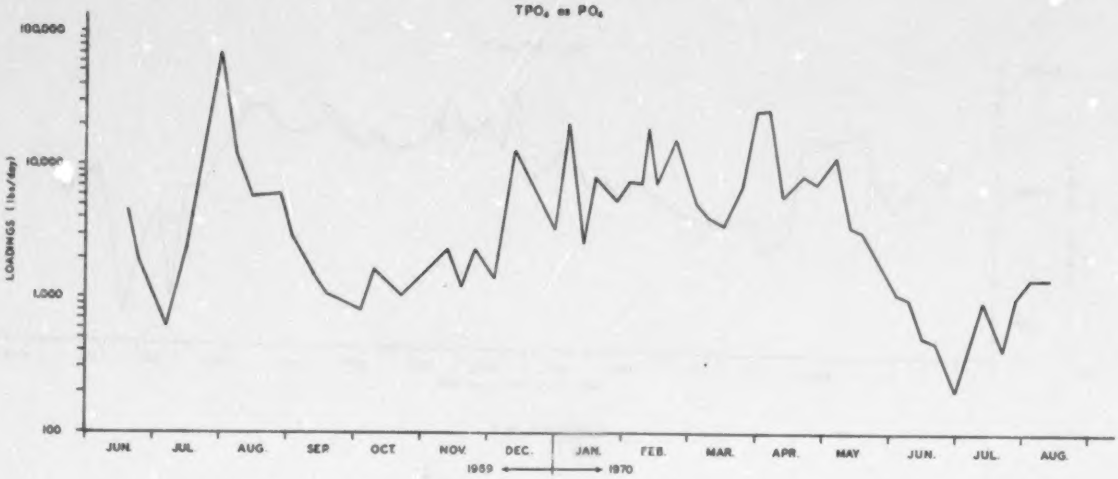
Seasonal Nutrient Loadings
James River at Richmond, Virginia

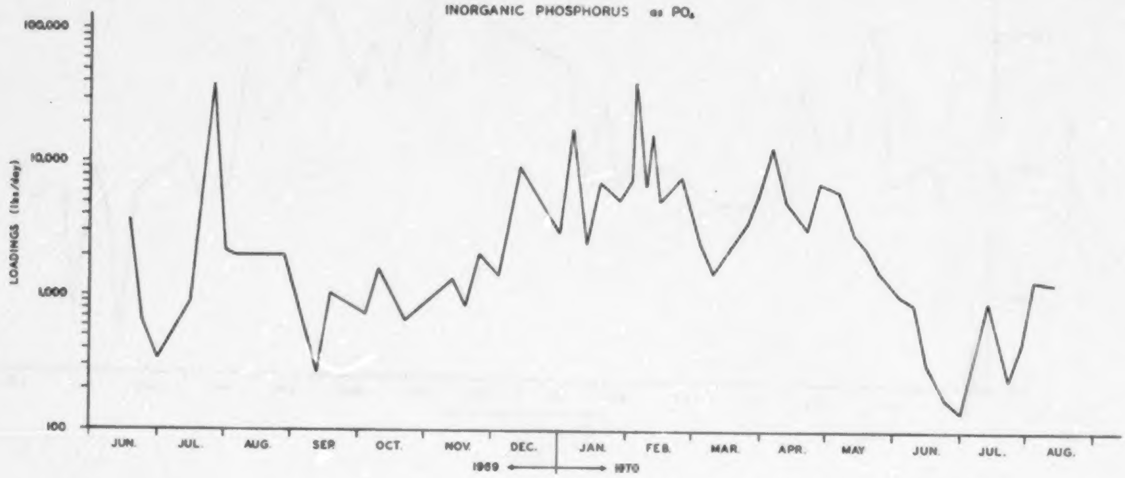
Nutrient Loadings (lbs/day)	June 1969 through October 1969*	November 1969 through May 1970	June 1970 throug August 1970
T.PO_4 as PO_4	8,000	8,000	700
Inorganic Phosphorus	4,000	7,000	600
T.K.N. as N	22,000	23,000	5,000
$NO_2 + NO_3$ as N	12,000	20,000	9,000
NH_3 as N	2,000	7,000	400
T.O.C.	218,000	203,000	41,000

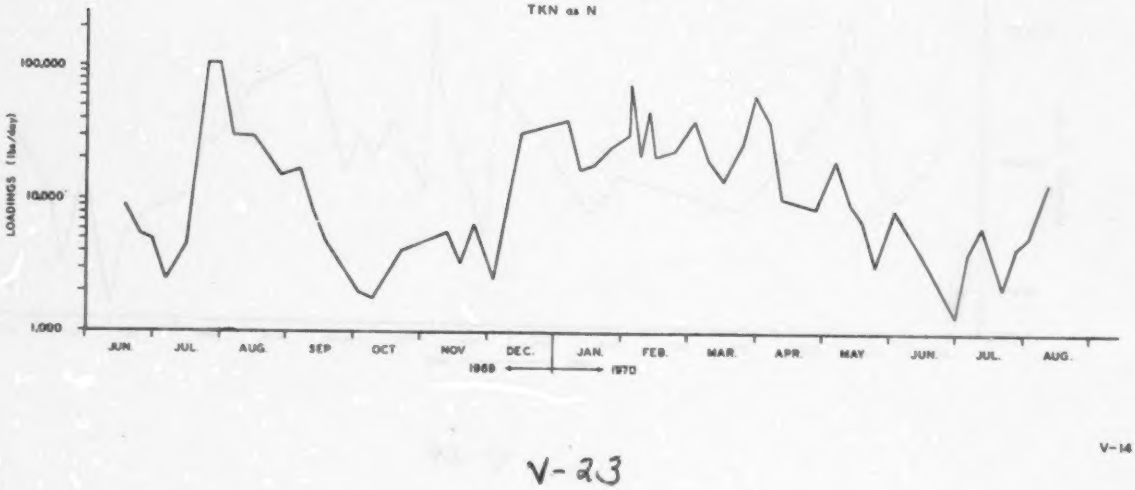
* Extreme river discharges during the months of July and August 1969 are reflected in nutrient loadings for this period.

JAMES RIVER AT RICHMOND, VIRGINIA

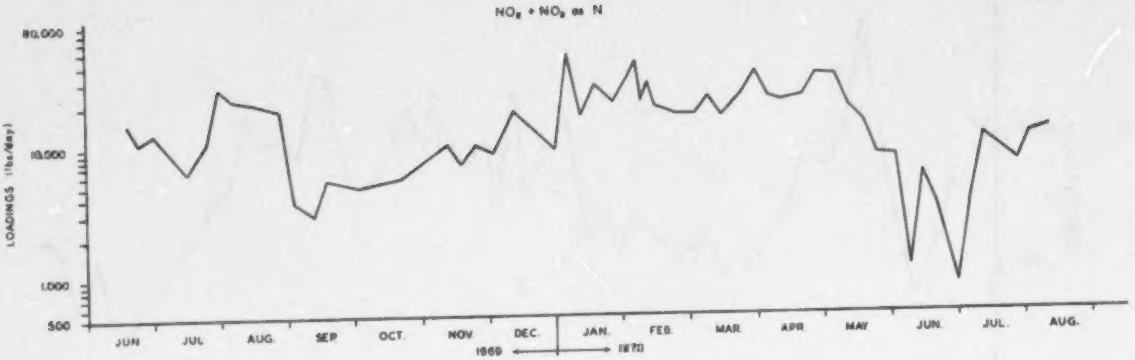
ACTUAL DAILY NUTRIENT LOADINGS

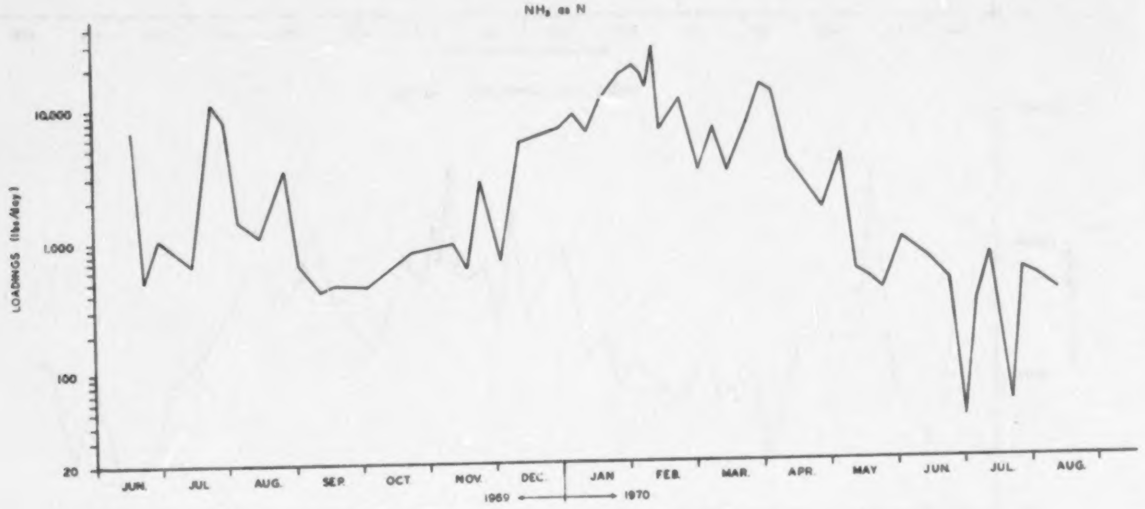

TPO$_4$ as PO$_4$


INORGANIC PHOSPHORUS as PO$_4$


TKN as N

JAMES RIVER AT RICHMOND, VIRGINIA
ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)





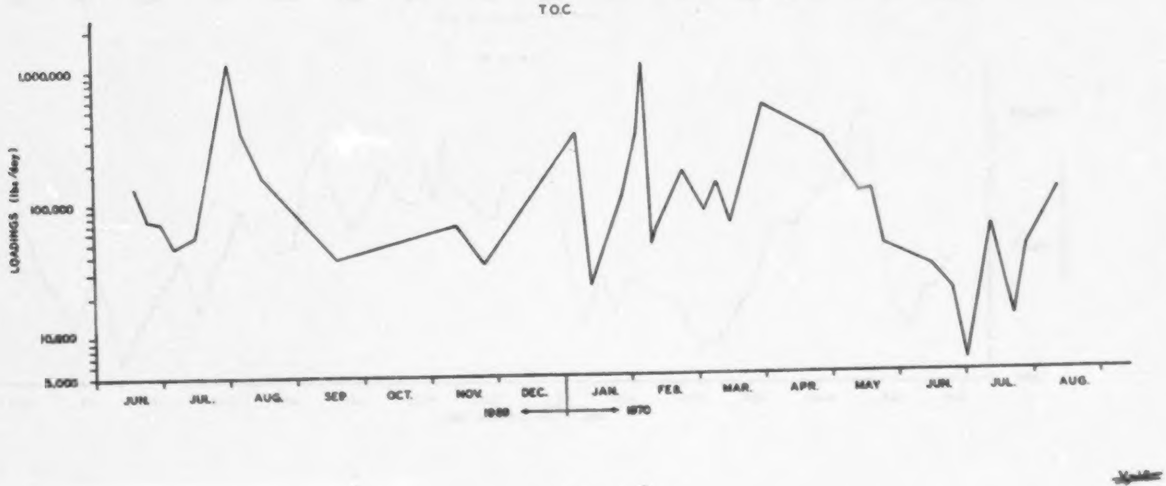


Table V - 9

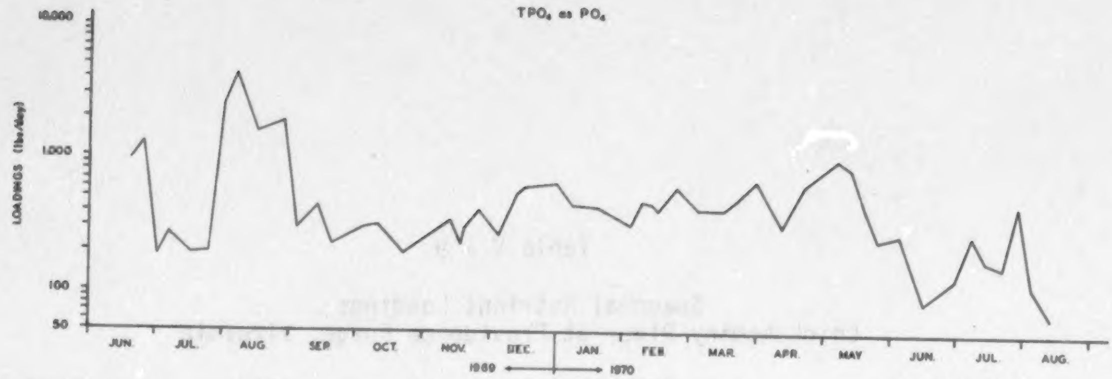
Seasonal Nutrient Loadings
Chickahominy River at Providence Forge, Virginia

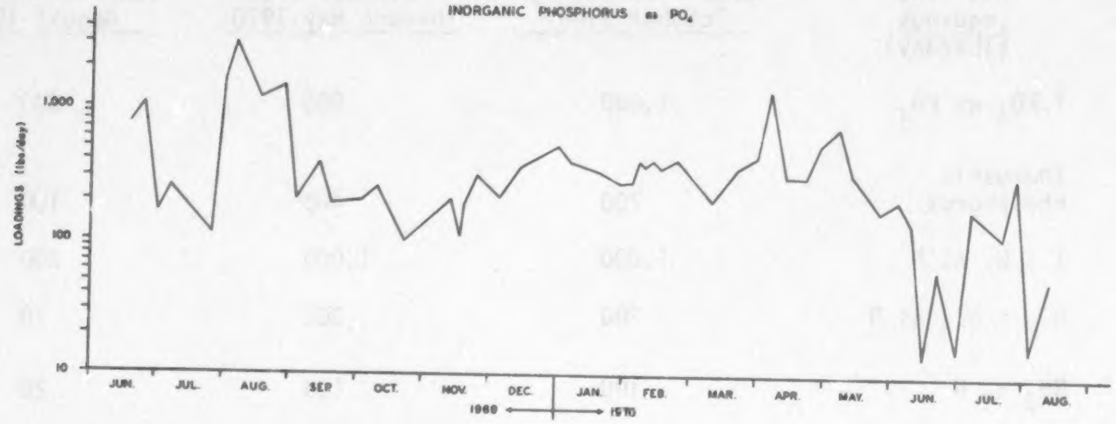
Nutrient Loadings (lbs/day)	June 1969 through October 1969*	November 1969 through May 1970	June 1970 through August 1970
$T.PO_4$ as PO_4	1,000	500	200
Inorganic Phosphorus	700	400	100
T.K.N. as N	1,000	1,000	200
$NO_2 + NO_3$ as N	300	300	70
NH_3 as N	100	100	20
T.O.C.	34,000	12,000	2,000

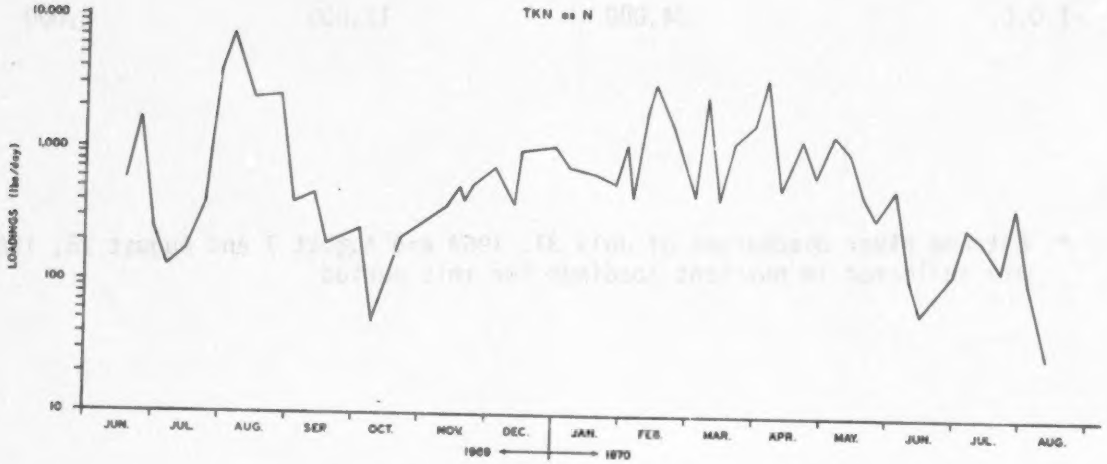
* Extreme river discharges of July 31, 1969 and August 7 and August 28, 1969 are reflected in nutrient loadings for this period.

CHICKAHOMINY RIVER AT PROVIDENCE FORGE, VIRGINIA

ACTUAL DAILY NUTRIENT LOADINGS

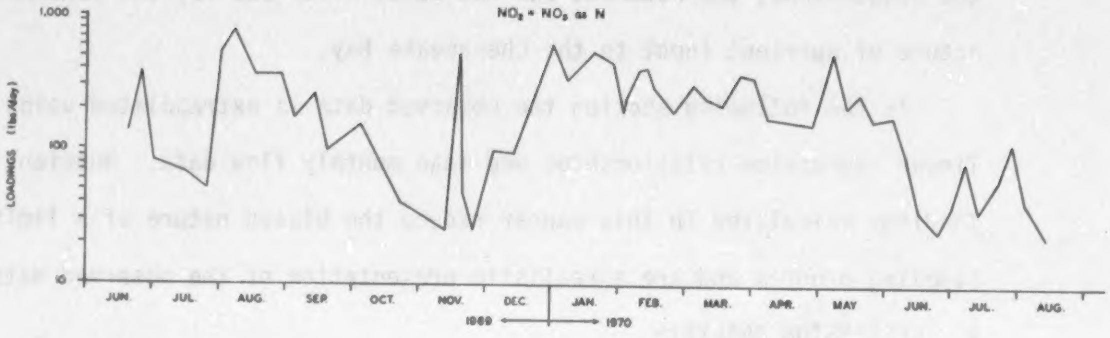


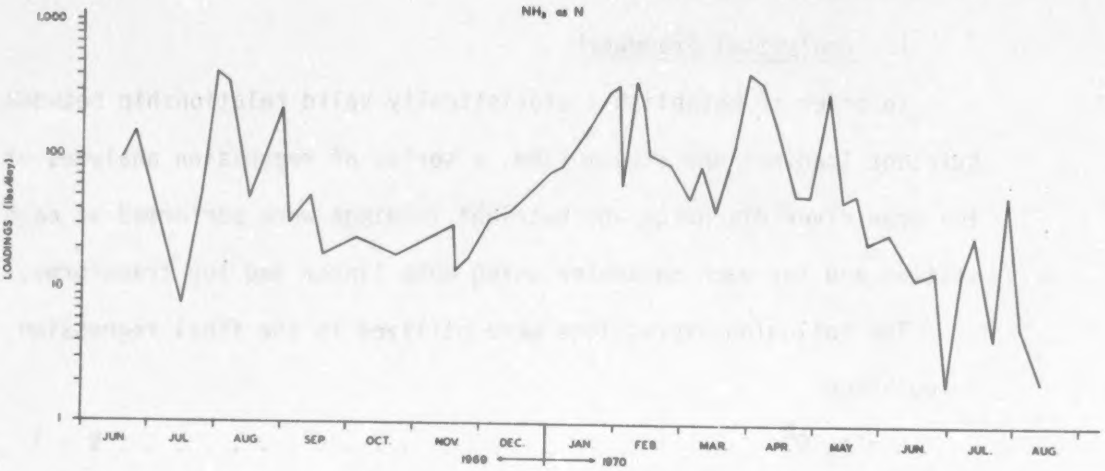


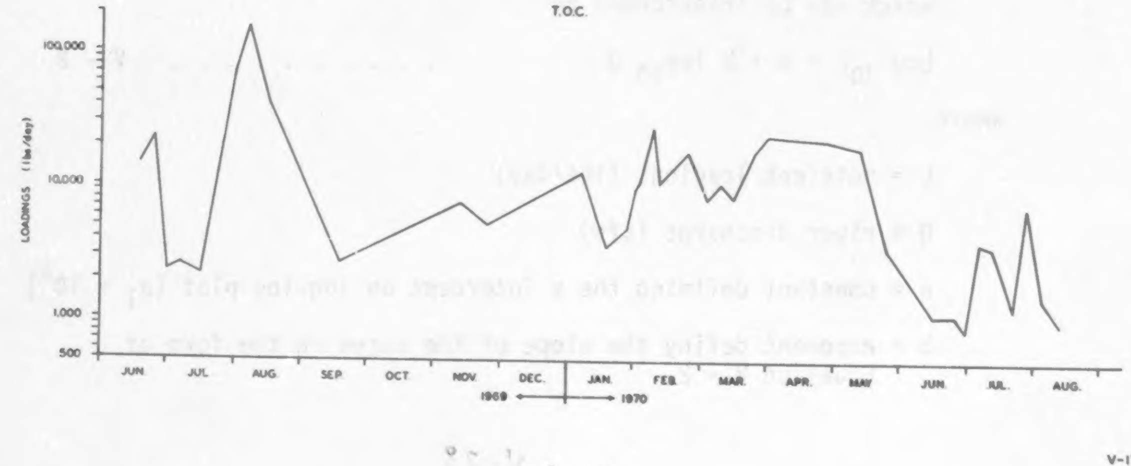


CHICKAHOMINY RIVER AT PROVIDENCE FORGE, VIRGINIA

ACTUAL DAILY NUTRIENT LOADINGS (CONTINUED)







As exhibited, nutrient contributions to the Chesapeake Bay from major watersheds based on calculated loadings using observed data indicate two distinct observations: (1) the predominate influence of three principal watersheds on the nutrient balance in the Chesapeake Bay--the Susquehanna, the Potomac, and the James River and (2) the seasonal nature of nutrient input to the Chesapeake Bay.

In the following section the observed data is extrapolated using linear regression relationships and mean monthly flow data. Nutrient loadings calculated in this manner reduce the biased nature of a limited sampling program and are a realistic presentation of the observed data.

B. REGRESSION ANALYSIS

1. Analytical Framework

In order to establish a statistically valid relationship between nutrient loadings and stream flow, a series of regression analyses of the mean river discharge and nutrient loadings were performed at each station and for each parameter using both linear and log transforms.

The following expressions were utilized in the final regression formulation:

$$L = a_1 Q^b \quad \text{. . . . . V - 1}$$

which may be transformed to

$$\text{Log}_{10} L = a + b \log_{10} Q \quad \text{. . . . . V - 2}$$

where

L = nutrient loadings (lbs/day)

Q = river discharge (cfs)

a = constant defining the y intercept on log-log plot ($a_1 = 10^a$)

b = exponent defing the slope of the curve in the form of Equation V - 2.

This equation represents an expotential function which is linear when plotted on log-log paper. The "b" term, or slope, is of particular importance since it signifies the rate at which nutrient loadings increase for any given flow.

The equation used to calculate nutrient loadings is

$$L = N \times Q \times 5.38$$

where

L = nutrient load (lbs/day)
N = nutrient concentration (mg/l)
Q = river discharge (cfs)
5.38 = conversion factor

It should be noted that the above form of the equation results in a biased analysis of L (nutrient loadings) versus Q (river discharge).

The derived least squares regression equations (Equation V - 2) and related statistics which describe nutrient load-streamflow relationships for each tributary watershed are presented in this report.

Utilization of the derived regression equations and graphs enable the calculation of nutrient loadings at each sampling station using either the mean monthly flows which occurred during the study period or any other desirable flow. The use of mean monthly flows in nutrient load calculations reduces the biased nature of a limited sampling program which realized only approximately 5 samples per month per station during the entire study period.

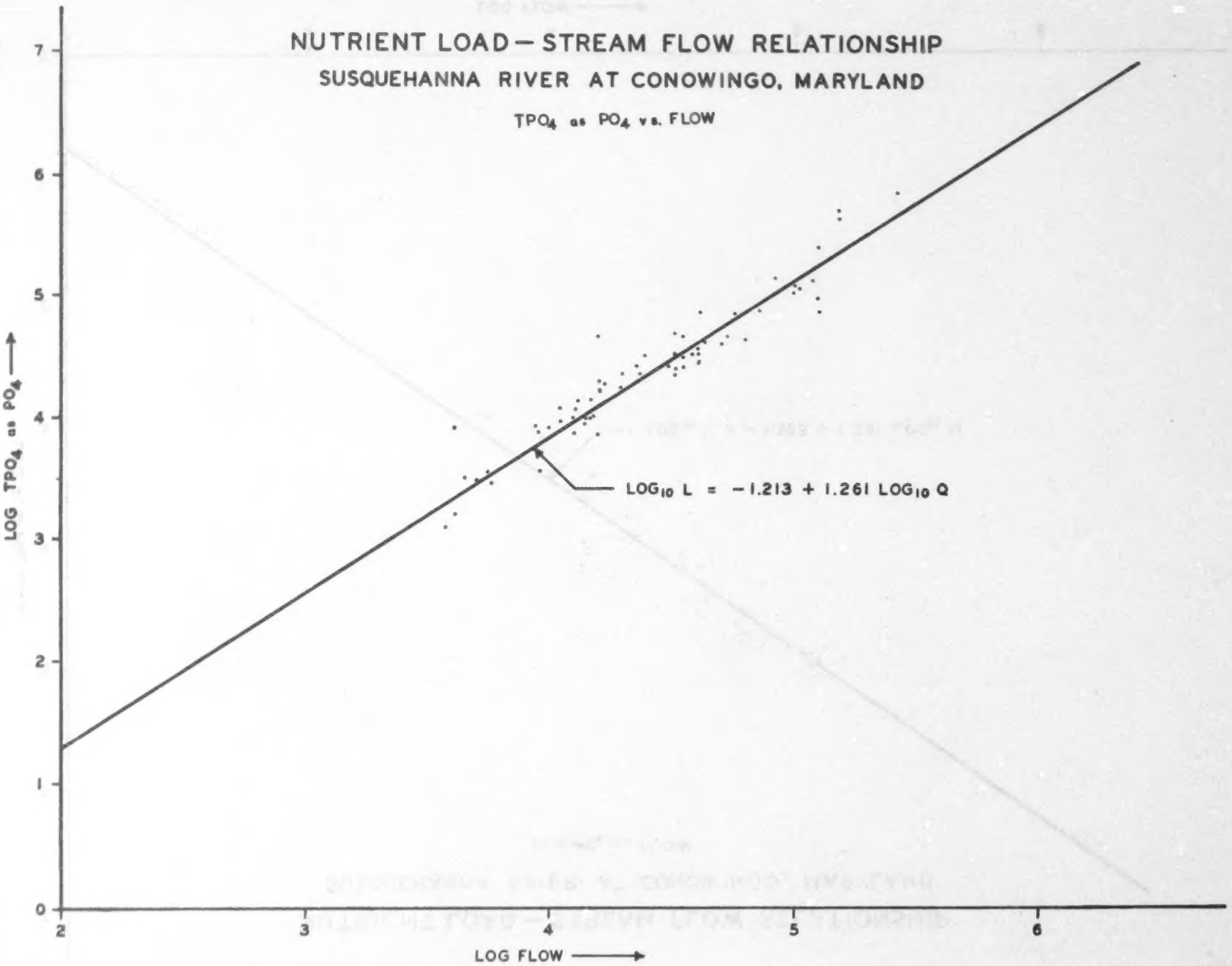
2. Regression Loadings (calculated)

A regression analysis of nutrient loadings (lbs/day) versus river discharge (cfs) was performed for every station in the study network.

These regression analyses were calculated using the United States Geological Survey Statistical Package (STATPAC) - a computer program which eliminates the cumbersome task of manual calculation of regression data for each parameter at every tributary watershed.

Least squares regression lines in the form of Equation V - 2, which describe the nutrient load - streamflow relationships for each parameter at the Susquehanna River station, are illustrated in Figures V - 18 through V - 23. Only the regression lines for the Susquehanna River station are presented because of the major importance of the Susquehanna River and also for the sake of brevity. The least squares regression lines (log-log plots) show the dependence of nutrient loadings for any particular river discharge and also verify the reliability of the regression extrapolation (to visualize the correlations of the observed data to the regression lines).

The regression equations, correlation coefficients and related statistics utilized to determine the extrapolated nutrient loadings at each station in the sampling network are presented in Tables V - 10 through V - 17. The regression equation in the form of Equation V - 1 was used to compute the nutrient loadings.



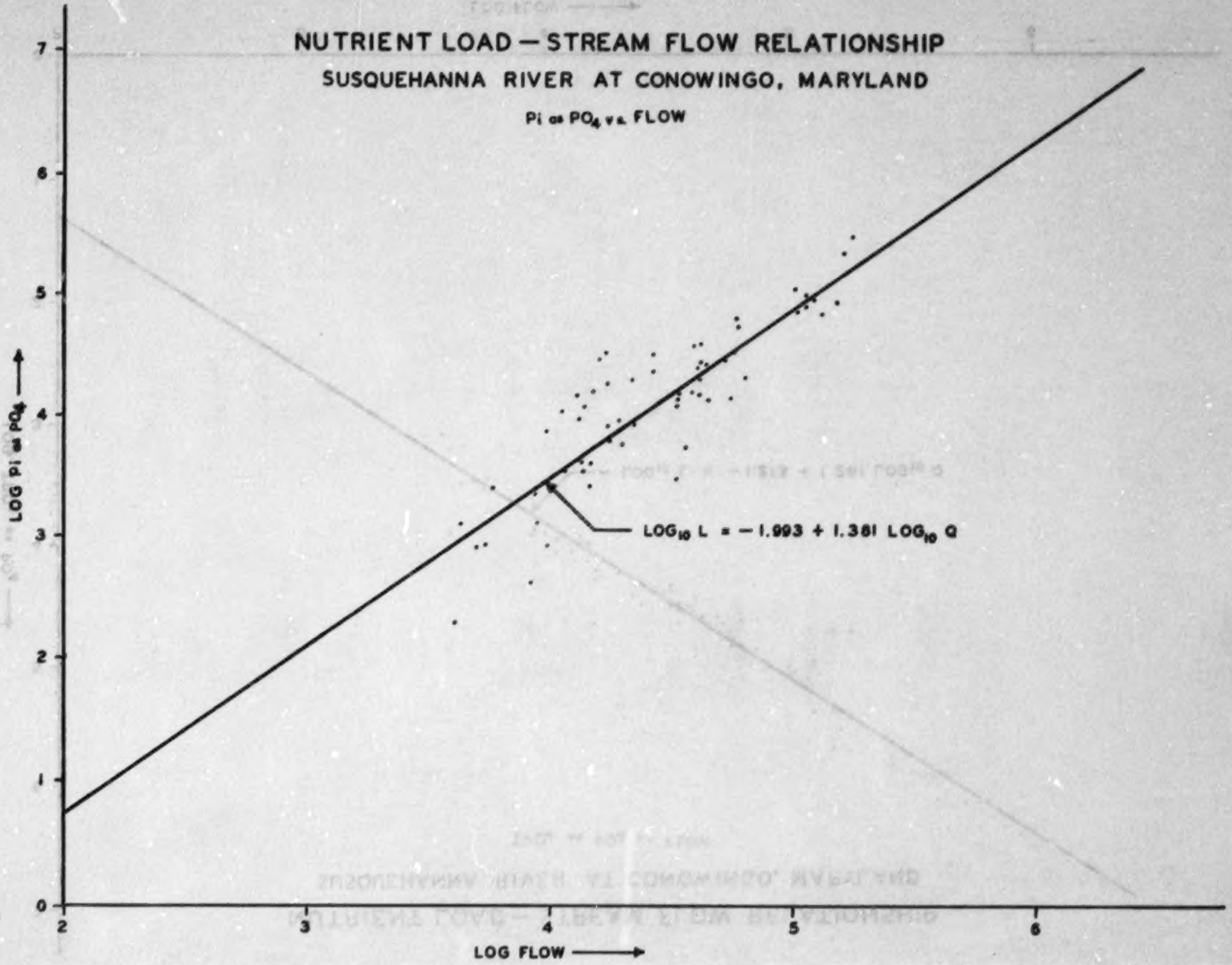
NUTRIENT LOAD—STREAM FLOW RELATIONSHIP
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

TPO_4 as PO_4 vs. FLOW

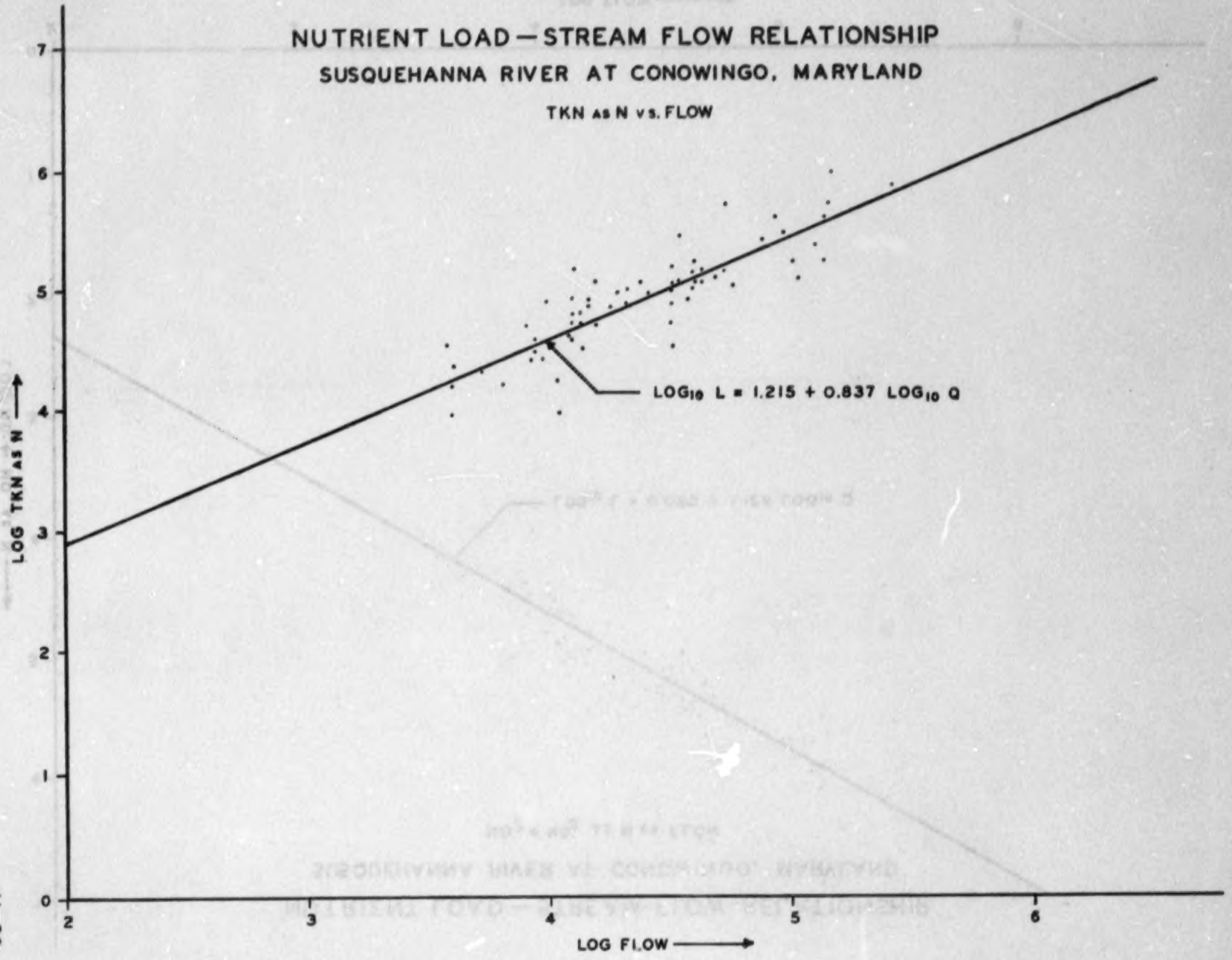
NUTRIENT LOAD — STREAM FLOW RELATIONSHIP

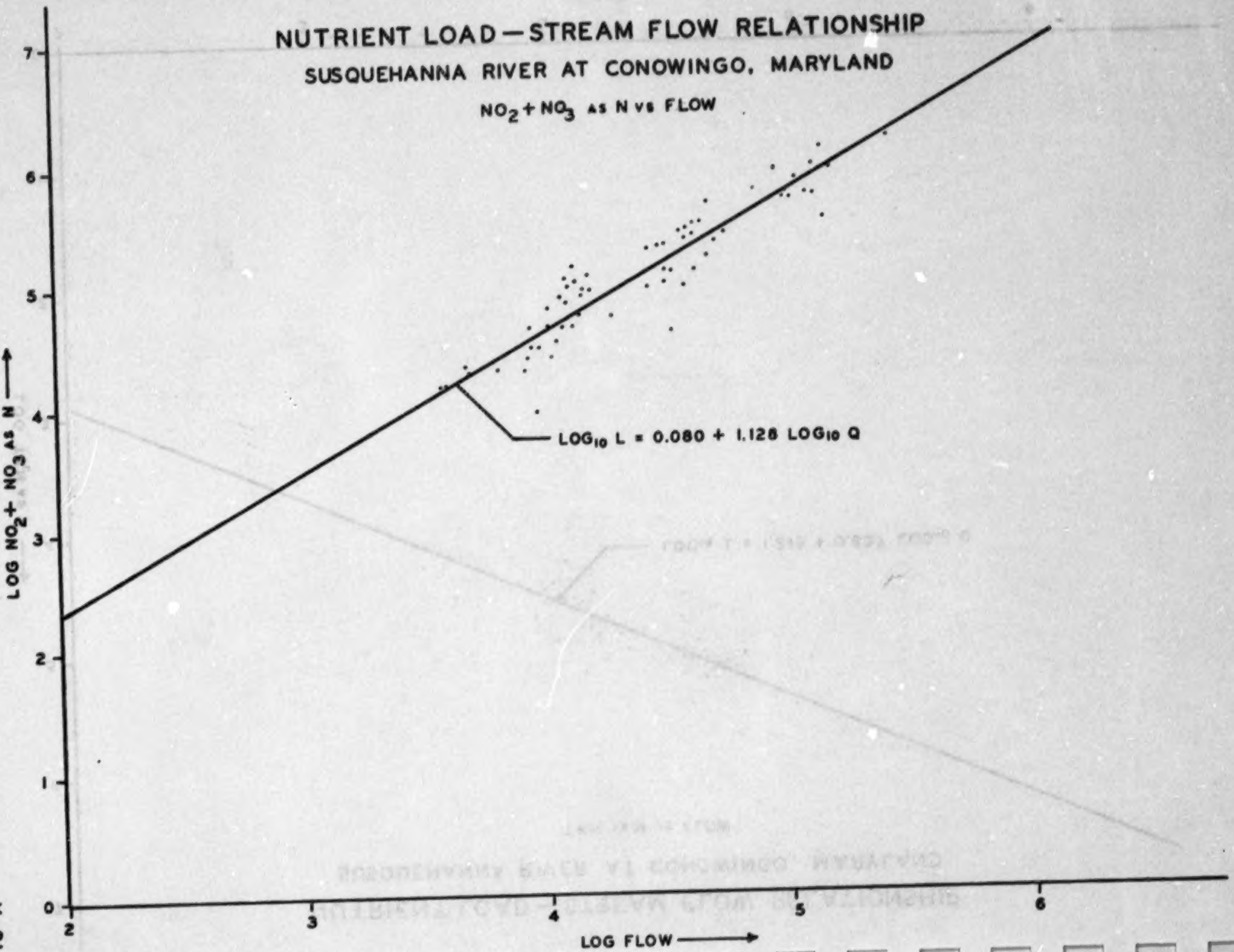
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

Pi as PO_4 vs. FLOW



NUTRIENT LOAD—STREAM FLOW RELATIONSHIP
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND
TKN AS N vs. FLOW





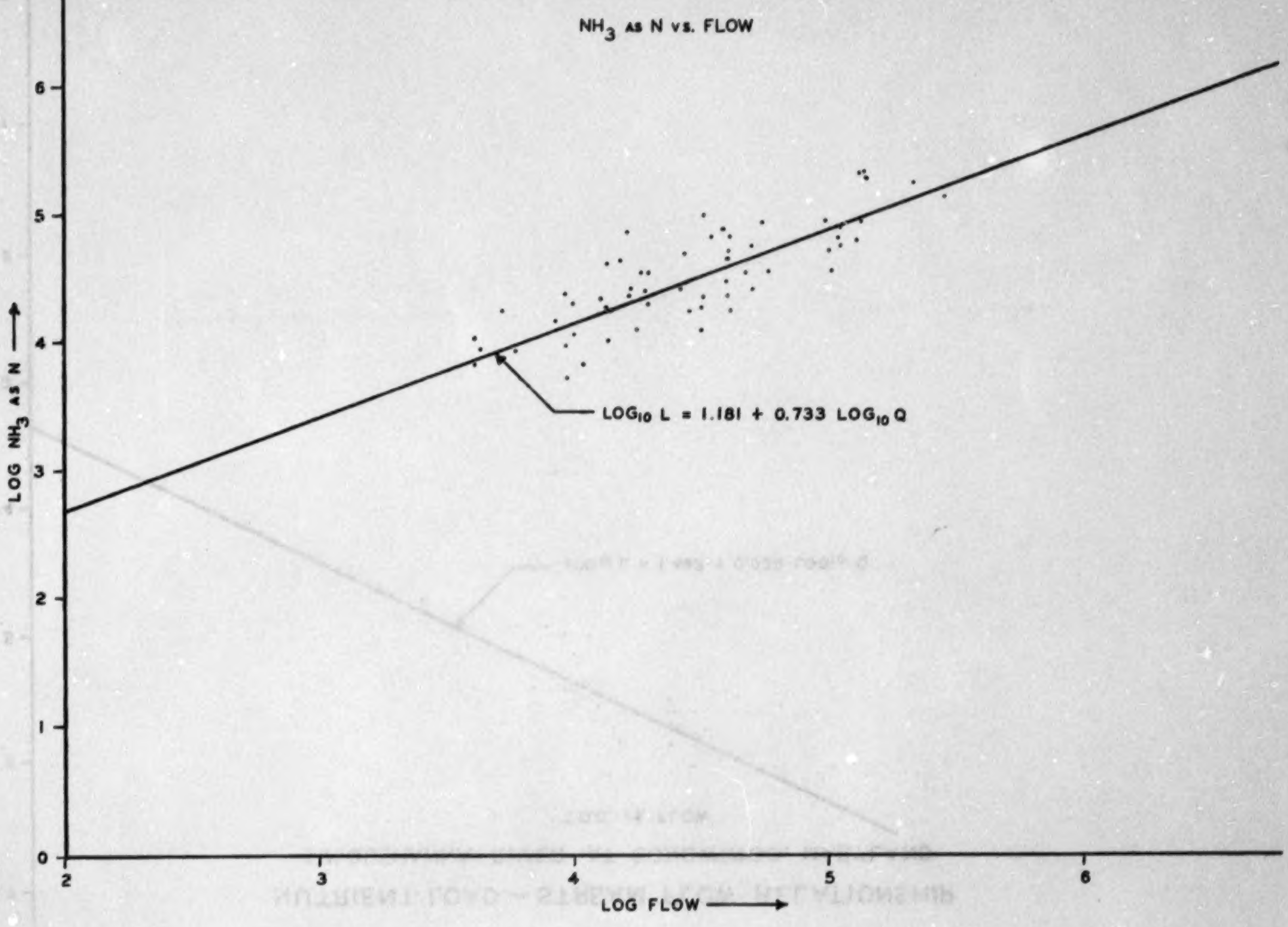
NUTRIENT LOAD—STREAM FLOW RELATIONSHIP

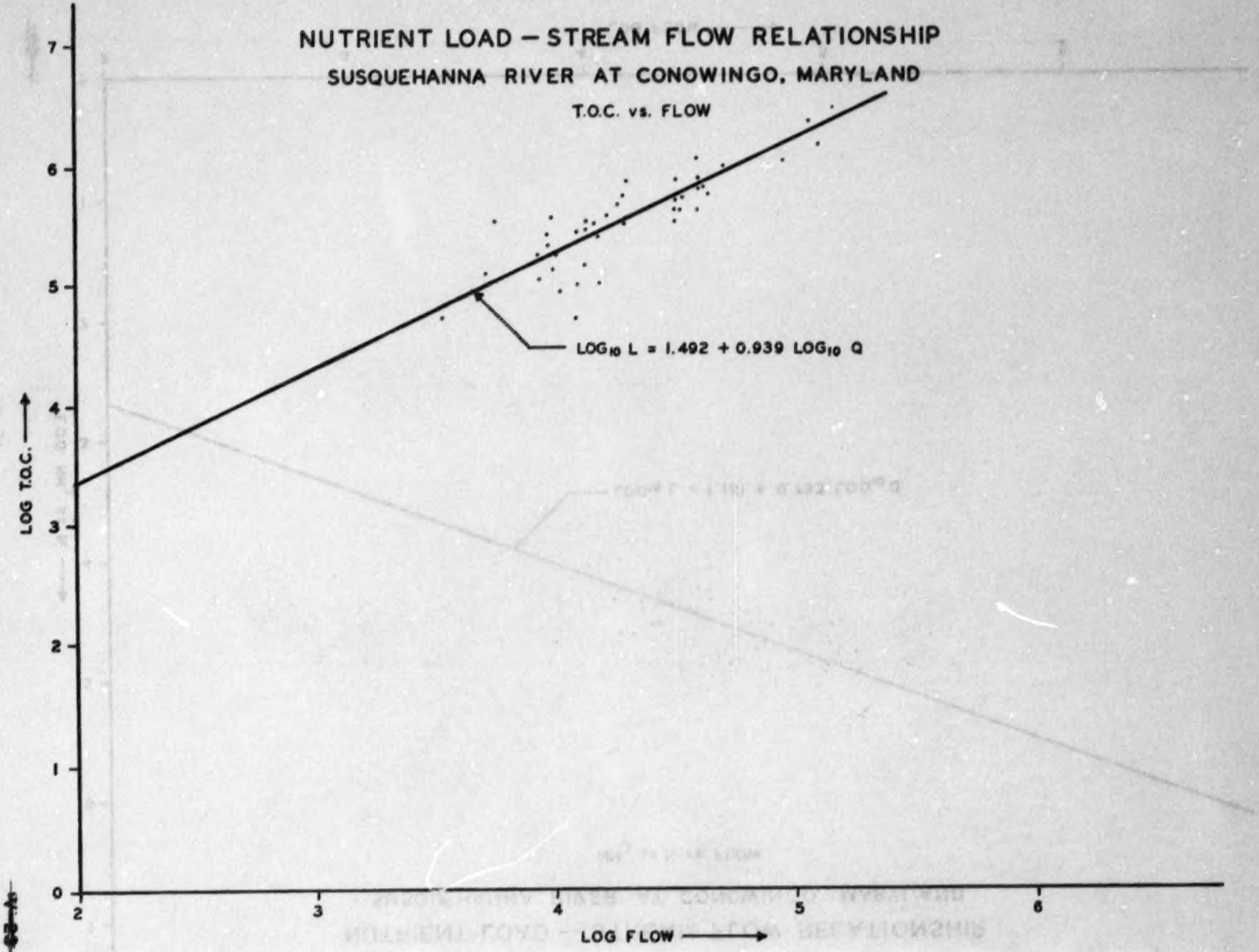
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

$NO_2 + NO_3$ AS N vs FLOW

NUTRIENT LOAD — STREAM FLOW RELATIONSHIP
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

NH_3 AS N vs. FLOW





NUTRIENT LOAD – STREAM FLOW RELATIONSHIP
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND
T.O.C. vs. FLOW

Table V - 10
Regression Study Results
Susquehanna River at Conowingo, Maryland

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 0.061\ Q^{1.261}$	0.96	25.70	63
P (Inorganic)	$L = 0.010\ Q^{1.381}$	0.89	15.03	60
TKN as N	$L = 16.410\ Q^{.837}$	0.86	12.94	62
$NO_2 + NO_3$ as N	$L = 1.202\ Q^{1.128}$	0.93	19.65	59
NH_3 as N	$L = 15.170\ Q^{.733}$	0.76	8.73	58
TOC	$L = 31.050\ Q^{.939}$	0.85	10.07	41

* test of significance

** = number of observations (n)-1

Table V - 11
Regression Study Results
Patuxent River at Route 50 (John Hanson Highway)

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 101.200\ Q^{.635}$	0.70	7.42	57
P (Inorganic)	$L = 530.900\ Q^{.269}$	0.43	3.45	55
TKN as N	$L = 7.465\ Q^{1.020}$	0.90	14.83	55
$NO_2 + NO_3$ as N	$L = 60.120\ Q^{.615}$	0.88	13.79	58
NH_3 as N	$L = 13.870\ Q^{.807}$	0.79	9.58	58
TOC	$L = 11.380\ Q^{1.201}$	0.83	9.13	38

* test of significance

** = number of observations (n)-1

Table V - 12
Regression Study Results
Potomac River at Great Falls, Maryland

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 1.223\ Q^{1.068}$	0.89	18.69	91
P (Inorganic)	$L = 0.150\ Q^{1.203}$	0.87	15.87	83
TKN as N	$L = 8.577\ Q^{.908}$	0.78	12.05	93
$NO_2 + NO_3$ as N	$L = 0.041\ Q^{1.517}$	0.89	18.04	91
NH_3 as N	$L = 1.023\ Q^{.951}$	0.74	10.32	88
TOC	$L = 152.100\ Q^{.817}$	0.76	8.67	55

* test of significance

** = number of observations (n)-1

Table V - 13
Regression Study Results
Rappahannock River at Fredericksburg, Virginia

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 0.142\ Q^{1.289}$	0.89	14.65	56
P (Inorganic)	$L = 0.067\ Q^{1.315}$	0.90	15.37	54
TKN as N	$L = 1.246\ Q^{1.113}$	0.89	14.63	55
$NO_2 + NO_3$ as N	$L = 0.028\ Q^{1.616}$	0.87	12.59	51
NH_3 as N	$L = 0.029\ Q^{1.364}$	0.85	11.21	51
TOC	$L = 17.870\ Q^{1.029}$	0.85	9.51	35

* test of significance

** = number of observations (n)-1

Table V - 14
Regression Study Results
Mattaponi River at Beulahville, Virginia

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 1.164\ Q^{.945}$	0.94	19.26	54
P (Inorganic)	$L = 0.588\ Q^{1.025}$	0.93	18.76	55
TKN as N	$L = 5.807\ Q^{.867}$	0.83	10.50	52
$NO_2 + NO_3$ as N	$L = 0.265\ Q^{1.110}$	0.85	11.73	53
NH_3 as N	$L = 0.119\ Q^{1.169}$	0.91	15.69	52
TOC	$L = 109.200\ Q^{.822}$	0.87	10.68	36

* test of significance

** = number of observations (n)-1

Table V - 15
Regression Study Results
Pamunkey River at Hanover, Virginia

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 0.154\ Q^{1.272}$	0.94	21.29	56
P (Inorganic)	$L = .220\ Q^{1.152}$	0.88	13.66	55
TKN as N	$L = 2.391\ Q^{1.012}$	0.89	14.43	55
$NO_2 + NO_3$ as N	$L = 0.065\ Q^{1.394}$	0.91	16.19	54
NH_3 as N	$L = 0.065\ Q^{1.275}$	0.81	9.84	52
TOC	$L = 17.420\ Q^{1.076}$	0.88	11.27	38

* test of significance

** = number of observations (n)-1

Table V - 16
Regression Study Results
James River at Richmond, Virginia

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 0.101\ Q^{1.276}$	0.95	21.59	54
P (Inorganic)	$L = 0.110\ Q^{1.209}$	0.88	13.23	53
TKN as N	$L = 2.797\ Q^{1.012}$	0.89	14.16	55
$NO_2 + NO_3$ as N	$L = 19.590\ Q^{.780}$	0.86	11.87	52
NH_3 as N	$L = 0.025\ Q^{1.370}$	0.85	11.71	52
TOC	$L = 33.960\ Q^{.965}$	0.85	9.64	37

* test of significance

** = number of observations (n)-1

Table V - 17
Regression Study Results
Chickahominy River at Providence Forge, Virginia

Parameter	Regression Equation	Correlation Coefficient	T-Value*	Degrees of Freedom**
T. PO_4 as PO_4	$L = 14.030\ Q^{.667}$	0.88	13.68	55
P (Inorganic)	$L = 4.775\ Q^{.806}$	0.85	11.97	55
TKN as N	$L = 4.875\ Q^{.936}$	0.89	14.78	56
$NO_2 + NO_3$ as N	$L = 4.989\ Q^{.694}$	0.78	8.95	51
NH_3 as N	$L = 0.224\ Q^{1.079}$	0.89	13.52	50
TOC	$L = 59.300\ Q^{.974}$	0.93	15.50	36

* test of significance

** = number of observations (n)-1

The mean monthly nutrient input (lbs/day) to the Chesapeake Bay from the major tributary watersheds* based on regression extrapolation using mean monthly flow data are presented in Tables V - 18 through V - 24.

The nitrogen and phosphorus inputs to the Chesapeake Bay from these major tributary watersheds are illustrated in Figures V - 24 and V - 25, respectively.

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*Patuxent River excluded due to limited flow data

Table V - 18
Nutrient Input of Susquehanna River at Conowingo, Maryland*

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	NO_2 + NO_3 as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	19,200	15,000	8,000	63,000	82,000	21,000	327,000
07/69	14,900	11,000	6,000	51,000	61,000	17,000	258,000
08/69	18,000	14,000	8,000	60,000	76,000	20,000	308,000
09/69	6,300	4,000	2,000	25,000	23,000	9,000	115,000
10/69	5,000	3,000	1,000	21,000	18,000	8,000	93,000
11/69	25,900	22,000	12,000	81,000	114,000	26,000	433,000
12/69	31,100	28,000	16,000	95,000	141,000	30,000	514,000
01/70	18,700	15,000	8,000	62,000	79,000	21,000	319,000
02/70	67,200	75,000	46,000	181,000	335,000	52,000	1,000,000
03/70	50,300	52,000	31,000	141,000	242,000	42,000	807,000
04/70	132,800	176,000	119,000	319,000	723,000	86,000	2,000,000
05/70	41,200	40,000	24,000	120,000	193,000	37,000	670,000
06/70	20,400	17,000	9,000	66,000	87,000	22,000	346,000
07/70	20,400	17,000	9,000	66,000	87,000	22,000	346,000
08/70	10,600	7,000	4,000	38,000	42,000	14,000	187,000
TOTAL	482,000	496,000	303,000	1,400,000	2,300,000	427,000	7,700,000
AVG.MO.	32,133	33,000	20,000	93,000	153,000	29,000	513,000

* Regression extrapolation using mean monthly flows

Table V - 19
Nutrient Input of Potomac River at Great Falls, Maryland*

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	2,685	6,000	2,000	11,000	7,000	2,000	96,000
07/69	2,954	6,000	2,000	12,000	7,000	2,000	102,000
08/69	8,461	19,000	8,000	32,000	37,000	6,000	246,000
09/69	4,812	10,000	4,000	19,000	16,000	3,000	155,000
10/69	2,327	5,000	2,000	10,000	5,000	2,000	86,000
11/69	3,626	8,000	3,000	15,000	10,000	2,000	123,000
12/69	7,952	18,000	7,000	30,000	34,000	5,000	233,000
01/70	11,958	28,000	12,000	43,000	63,000	8,000	326,000
02/70	21,390	52,000	24,000	73,000	152,000	13,000	524,000
03/70	16,104	38,000	17,000	57,000	99,000	10,000	416,000
04/70	34,593	86,000	43,000	113,000	315,000	21,000	777,000
05/70	9,216	21,000	9,000	34,000	42,000	6,000	263,000
06/70	6,204	14,000	5,000	24,000	23,000	4,000	191,000
07/70	8,627	20,000	8,000	32,000	38,000	6,000	250,000
08/70	3,606	8,000	3,000	15,000	10,000	2,000	123,000
TOTAL	144,515	339,000	149,000	520,000	858,000	92,000	4,000,000
AVG.MO.	9,634	23,000	9,900	35,000	57,000	6,000	267,000

* Regression extrapolation using mean monthly flow

Table V - 20
Nutrient Input of Rappahannock River at Fredericksburg, Virginia*

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	692	700	400	1,800	1,100	200	15,000
07/69	1,132	1,200	600	3,000	2,100	400	25,000
08/69	1,245	1,400	800	3,500	2,500	500	27,000
09/69	540	500	300	1,500	700	200	12,000
10/69	511	400	300	1,300	600	200	11,000
11/69	714	700	400	2,000	1,000	200	15,000
12/69	1,850	2,300	1,300	5,500	5,000	800	41,000
01/70	2,485	3,500	1,900	7,500	8,400	1,300	56,000
02/70	3,058	4,500	2,500	9,500	12,000	1,600	69,000
03/70	1,637	2,000	1,100	4,700	4,000	700	36,000
04/70	2,922	4,000	2,400	9,000	11,000	1,600	66,000
05/70	1,382	1,600	1,000	4,000	3,000	600	31,000
06/70	521	500	300	1,300	600	200	11,000
07/70	774	700	400	2,000	1,200	300	17,000
08/70	421	400	200	1,000	500	100	9,000
TOTAL	19,884	24,000	14,000	58,000	54,000	9,000	441,000
AVG.MO.	1,325	1,600	900	3,900	3,600	600	29,000

* Regression extrapolation using mean monthly flows

Table V - 21
Nutrient Input of Mattaponi River at Beulahville, Virginia*

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	NO_2 + NO_3 as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	162	200	100	500	100	50	7,100
07/69	180	200	100	500	100	50	7,800
08/69	2,409	1,800	1,700	5,000	1,500	1,000	65,000
09/69	293	300	200	800	200	100	11,000
10/69	202	200	200	500	100	50	8,500
11/69	282	200	200	700	200	100	11,000
12/69	789	600	600	1,800	500	300	26,000
01/70	1,104	900	800	2,500	600	500	35,000
02/70	1,060	800	800	2,500	600	400	33,000
03/70	719	600	500	1,700	400	300	24,000
04/70	1,418	1,100	1,000	3,100	800	600	43,000
05/70	526	400	400	1,300	300	200	19,000
06/70	125	100	100	400	50	50	5,800
07/70	215	200	200	600	100	100	9,000
08/70	62	50	50	200	50	50	3,200
TOTAL	9,546	7,700	7,000	22,000	5,600	3,900	308,000
AVG.MO.	636	500	450	1,500	400	250	20,500

* Regression extrapolation using mean monthly flows

Table V - 22
Nutrient Input of Pamunkey River at Hanover, Virginia*

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	602	500	400	1,600	500	300	17,000
07/69	778	700	500	2,000	700	300	22,000
08/69	6,381	11,000	5,300	17,000	13,000	4,700	219,000
09/69	409	300	200	1,100	300	100	11,000
10/69	271	200	100	700	200	100	7,200
11/69	341	300	200	900	200	100	9,200
12/69	1,074	1,100	700	2,800	1,100	500	32,000
01/70	1,674	2,000	1,100	4,400	2,000	1,000	60,000
02/70	1,500	1,700	900	4,000	1,800	1,000	46,000
03/70	1,101	1,100	700	3,000	1,200	500	33,000
04/70	1,951	2,300	1,400	5,100	2,500	1,000	60,000
05/70	748	700	500	2,000	700	300	22,000
06/70	223	200	100	600	200	100	5,800
07/70	226	200	100	600	200	100	6,000
08/70	148	100	50	400	100	50	3,700
TOTAL	17,427	22,000	13,000	46,000	25,000	10,000	554,000
AVG.MO.	1,161	1,500	900	3,000	1,700	700	37,000

* Regression extrapolation using mean monthly flows

Table V - 23
Nutrient Input of James River at Richmond, Virginia*

Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	NO_2 + NO_3 as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	3,255	3,100	1,900	10,000	11,000	1,600	83,000
07/69	4,567	4,700	2,900	14,000	14,000	3,000	116,000
08/69	21,710	34,500	19,000	68,000	47,000	22,000	524,000
09/69	2,402	2,100	1,300	7,000	8,000	1,000	62,000
10/69	1,568	1,000	700	5,000	6,000	500	37,000
11/69	1,622	1,300	800	5,000	6,000	500	42,000
12/69	4,607	4,700	2,900	15,000	14,000	3,000	116,000
01/70	10,820	14,000	8,300	34,000	27,000	8,000	266,000
02/70	10,980	14,000	8,300	35,000	27,000	8,000	267,000
03/70	6,023	6,700	4,000	19,000	17,000	4,000	151,000
04/70	10,070	13,000	7,600	32,000	26,000	7,000	246,000
05/70	4,892	5,100	3,200	15,000	15,000	3,000	123,000
06/70	1,184	1,000	600	3,000	5,000	500	31,000
07/70	1,155	1,000	600	3,000	5,000	500	31,000
08/70	1,258	1,000	600	4,000	5,000	500	33,000
TOTAL	86,113	107,000	63,000	269,000	233,000	63,000	2,000,000
AVG.MO.	5,740	7,100	4,200	18,000	15,500	4,200	133,000

* Regression extrapolation using mean monthly flows

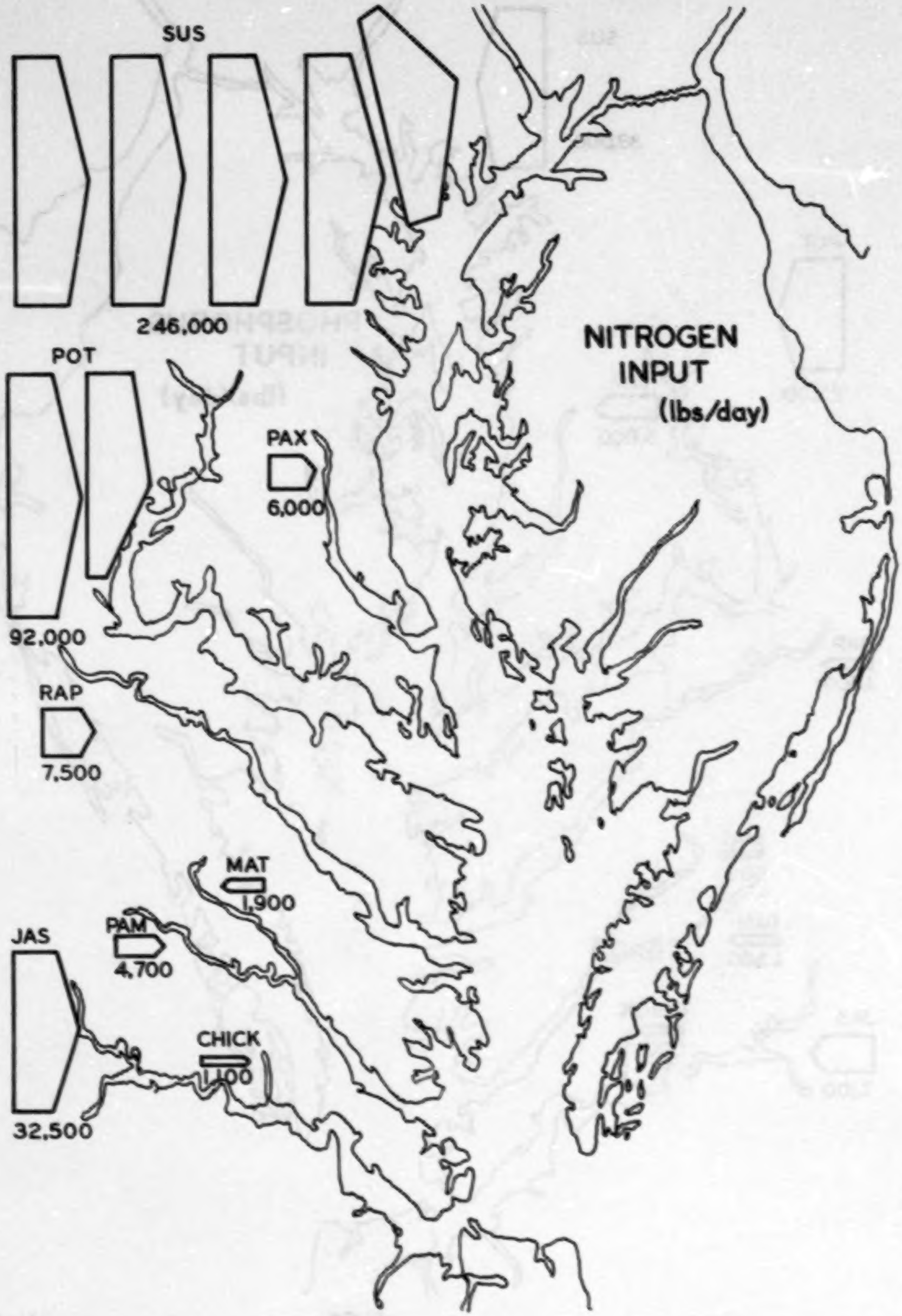
Table V - 24

Nutrient Input of Chickchominy River at Providence Forge, Virginia*

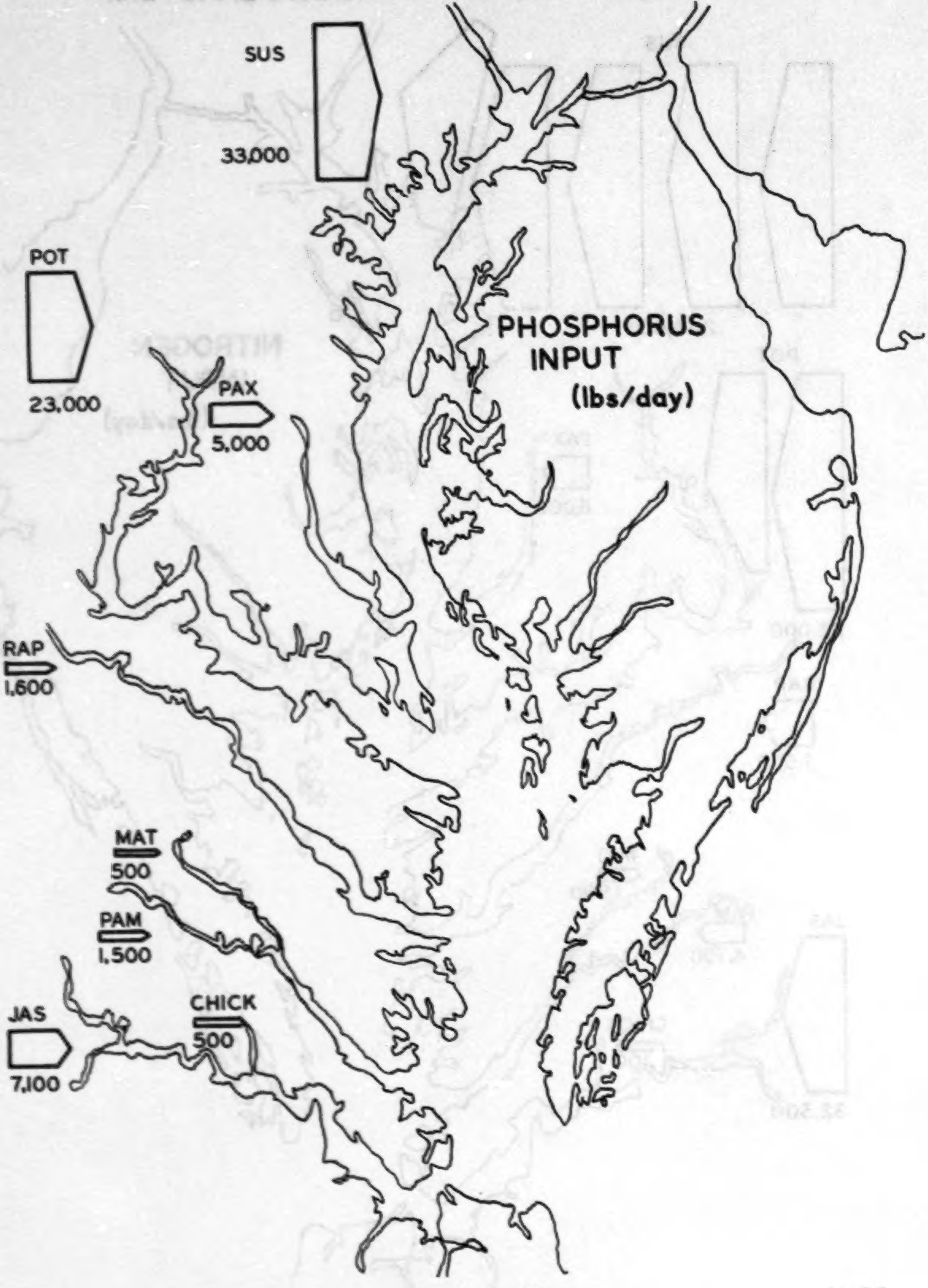
Date	Mean Flow (cfs)	T. PO_4 as PO_4 (lbs/day)	P (Inorganic) (lbs/day)	TKN as N (lbs/day)	$NO_2 + NO_3$ as N (lbs/day)	NH_3 as N (lbs/day)	TOC (lbs/day)
06/69	152	400	300	500	200	100	8,000
07/69	532	1,000	800	2,000	400	200	27,000
08/69	683	1,200	900	2,000	600	300	34,000
09/69	107	400	200	500	200	100	6,000
10/69	84	300	200	300	100	50	4,000
11/69	104	300	200	500	200	50	5,000
12/69	229	600	400	1,000	200	100	12,000
01/70	301	700	500	1,000	300	100	15,000
02/70	374	800	600	1,500	300	200	19,000
03/70	298	700	500	1,000	300	100	15,000
04/70	421	900	600	1,500	300	200	21,000
05/70	163	400	300	600	200	100	8,000
06/70	35	200	100	200	100	50	2,000
07/70	83	300	200	300	100	50	4,000
08/70	21	100	50	100	100	50	1,000
TOTAL	3,587	8,300	6,000	13,000	3,600	1,800	181,000
AVG.MO.	239	500	400	900	200	120	12,000

* Regression extrapolation using mean monthly flows

NITROGEN INPUT TO CHESAPEAKE BAY


SUS
246,000
NITROGEN
INPUT
(lbs/day)
POT
92,000
PAX
6,000
RAP
7,500
MAT
1,900
PAM
4,700
JAS
32,500
CHICK
1,100

PHOSPHORUS INPUT TO CHESAPEAKE BAY


SUS
33,000
POT
23,000
PAX
5,000
RAP
1,600
MAT
500
PAM
1,500
JAS
7,100
CHICK
500
PHOSPHORUS
INPUT
(lbs/day)

C. DELINEATION OF MEAN MONTHLY NUTRIENT LOADINGS (REGRESSION)*

The tabulation of seasonal nutrient loadings for the major tributary watersheds based on regression extrapolation for the periods of June 1969 through October 1969, November 1969 through May 1970, and June 1970 through August 1970 are presented in Tables V - 25, V - 26, and V - 27, respectively. The seasonal nature of nutrient enrichment of the Chesapeake Bay is apparent when the 15-month study period is subdivided into three distinct time periods:

Table V - 25

Seasonal Nutrient Loadings (Regression Extrapolation)
June 1969 through October 1969
(lbs/day)

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
Susquehanna	9,000	5,000	44,000	52,000	15,000	220,000
Potomac	9,000	4,000	17,000	14,000	3,000	137,000
Rappahannock**	500	300	2,000	1,400	300	18,000
Mattaponi***	200	200	600	100	100	9,000
Pamunkey***	400	300	1,400	400	200	14,000
Chickahominy***	400	200	400	200	100	6,000
James***	3,000	2,000	9,000	10,000	1,500	75,000

* Calculated from observed data using mean monthly flows and derived regression equations

** Months of July 1969 and August 1969 excluded due to extreme river discharge

*** Month of August 1969 excluded due to extreme river discharge

Table V - 26

Seasonal Nutrient Loadings (Regression Extrapolation)*
November 1969 through May 1970
(lbs/day)

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
Susquehanna	58,000	37,000	143,000	261,000	42,000	820,000
Potomac	36,000	16,000	52,000	102,000	9,000	380,000
Rappahannock	3,000	1,500	6,000	6,000	1,000	45,000
Mattaponi	700	600	1,900	500	300	27,000
Pamunkey	1,300	800	3,000	1,400	600	37,000
Chickahominy	600	400	1,000	300	100	14,000
James	8,000	5,000	22,000	19,000	5,000	173,000

Table V - 27

Seasonal Nutrient Loadings (Regression Extrapolation)*
June 1970 through August 1970
(lbs/day)

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
Susquehanna	14,000	7,000	57,000	72,000	19,000	293,000
Potomac	14,000	3,000	24,000	24,000	4,000	188,000
Rappahannock	500	300	1,400	800	200	12,000
Mattaponi	200	200	400	100	100	6,000
Pamunkey	200	100	500	200	100	5,000
Chickahominy	200	200	200	100	50	2,000
James	1,000	600	3,000	5,000	500	32,000

* Calculated from observed data using mean monthly flows and derived regression equations

Based on these loadings, the majority of nontidal nutrient input to the Chesapeake occurred during the months of November 1969 through May 1970 (a period of high river discharges) as shown in the table below:

Seasonal Nutrient Contribution (%)

Time Period	T. PO_4 as PO_4	Pi	TKN	$NO_2 + NO_3$ as N	NH_3 as N	TOC
June 1969 through October 1969	14	14	19	14	20	19
November 1969 through May 1970	67	73	59	68	57	60
June 1970 through August 1970	19	13	22	18	23	21

In addition, during the period November 1969 through May 1970, when the majority of nutrients were transported into the Chesapeake Bay via nontidal discharges, the primary sources of nutrients were the three major watersheds; the Susquehanna, the Potomac, and the James River.

Table V - 28

Tributary Contributions
(Nutrient Loadings as %)

Tributary Watershed	T. PO_4 as PO_4	Pi	TKN as N	$NO_2 + NO_3$ as N	NH_3 as N	TOC
Susquehanna	54	60	62	66	72	55
Potomac	34	26	23	26	16	25
Rappahannock	3	3	3	2	<2	3
Mattaponi	<1	1	<1	<1	<1	2
Pamunkey	1	1	1	<1	<1	2
Chickahominy	<1	1	<1	<1	<1	<1
James	7	8	10	5	9	12

As exhibited in the previous tables, the tributary contributions reflect two distinct observations which can be made with regard to nutrient enrichment of the Chesapeake Bay: (1) the predominant influence of three principal watersheds on the nutrient balance of the Chesapeake Bay--the Susquehanna, the Potomac, and the James and (2) the seasonal nature of nutrient enrichment of the Chesapeake Bay.

Based on observed data and substantiated by linear regression extrapolation of observed data using mean monthly flows, the majority of nutrients transported into the Chesapeake Bay via nontidal discharges occurred during the period November 1969 through May 1970. In addition, during this same time period, the primary sources of nutrients to the Bay were the three principal watersheds: the Susquehanna, the Potomac, and the James.* Of these three watersheds, the Susquehanna exerts the greatest influence on the nutrient balance in the Bay. Nutrient control in this major watershed should result in restored nutrient balance in the Upper Chesapeake Bay.

D. COMPARISON OF OBSERVED DAILY LOADINGS AND MEAN MONTHLY LOADINGS BASED ON REGRESSION EXTRAPOLATION

The mean monthly nutrient loadings calculated from observed data using mean monthly flows and the aforementioned regression relationships are a realistic extrapolation that eliminates the biased nature of the limited sampling program.

A comparison between the observed daily nutrient loadings and mean monthly nutrient loadings based on regression extrapolation show significant differences. When sampling occurred on days of high flow, the monthly loadings estimate based on these daily readings will be much higher than when irregular flows are absorbed over the entire monthly period as is done in the regression analyses.

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* also for the periods of June 1969 through October 1969 and June 1970 through August 1970

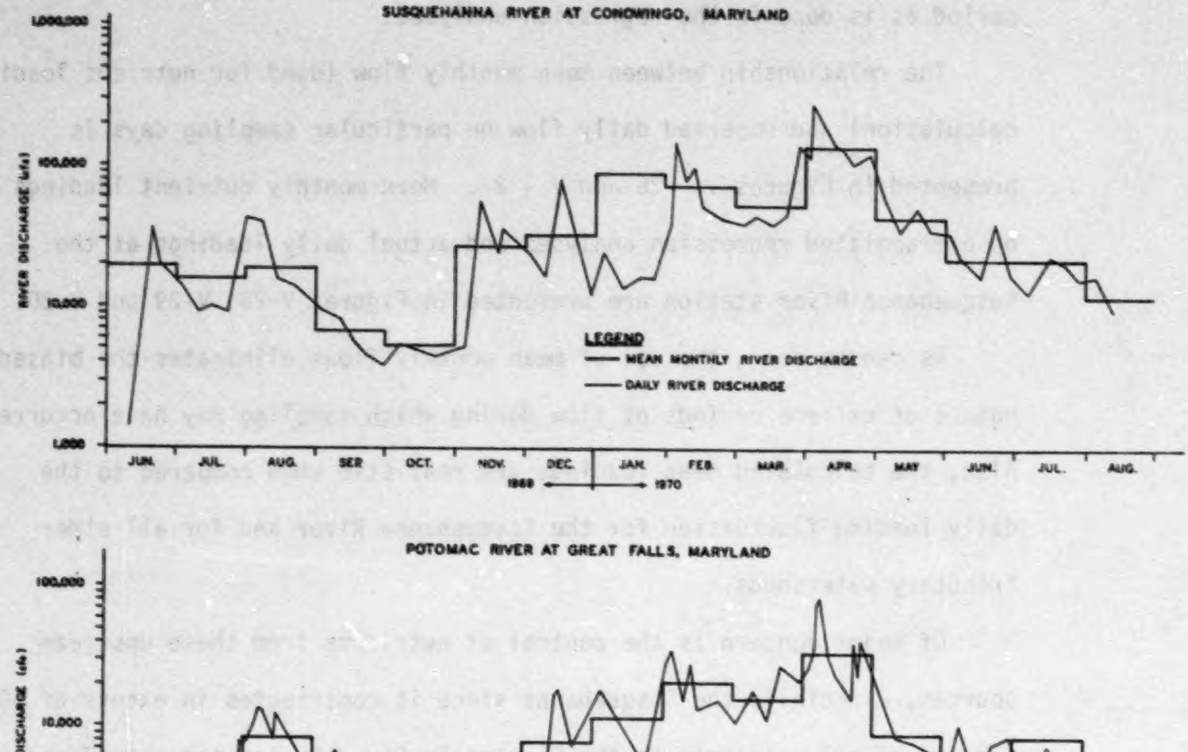
The relationship between mean monthly flow (used for nutrient loading calculation) and observed daily flow on particular sampling days is presented in Figures V - 26 and V - 27. Mean monthly nutrient loadings based on extrapolated regression analyses and actual daily loadings at the Susquehanna River station are presented in Figures V-28, V-29 and V-30.

As can be seen, the use of mean monthly flows eliminates the biased nature of extreme periods of flow during which sampling may have occurred. Also, the calculated mean loadings are realistic when compared to the daily loading fluctuation for the Susquehanna River and for all other tributary watersheds.

Of major concern is the control of nutrients from these upstream sources, especially the Susquehanna since it contributes in excess of 50 percent of all nutrients to the Chesapeake Bay. During the significant period of November 1969 through May 1970, which just precedes the ideal algal bloom season in the bay, the Susquehanna River Basin contributed 54 percent of total phosphorus, 60 percent of inorganic phosphorus, 62 percent of total kjeldahl nitrogen, 66 percent of nitrite-nitrate nitrogen, 72 percent of ammonia nitrogen and 55 percent of total organic carbon entering the Bay from the major tributary watersheds. As these upstream sources are brought under control on a seasonal or annual basis, especially in the Susquehanna River Basin, corresponding reduction in nuisance conditions in the Chesapeake Bay should result.

The importance of the vitality of the Susquehanna River to the ecological health of the Chesapeake Bay cannot, therefore be overstated.

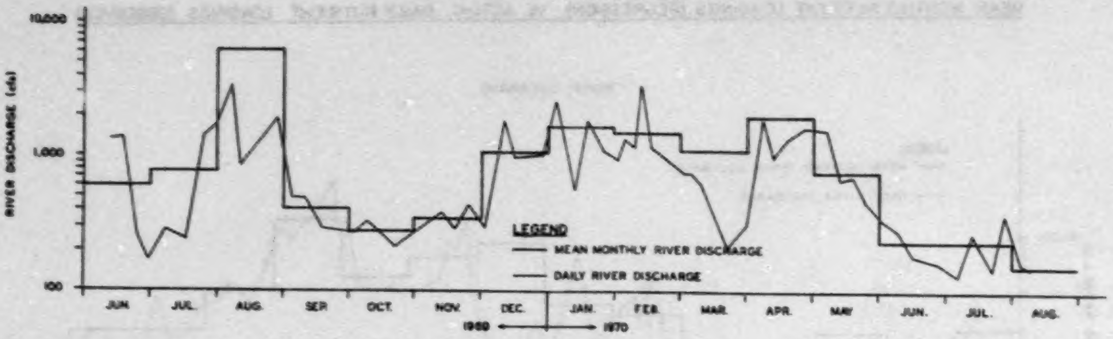
RIVER DISCHARGES
(MEAN MONTHLY vs. OBSERVED)



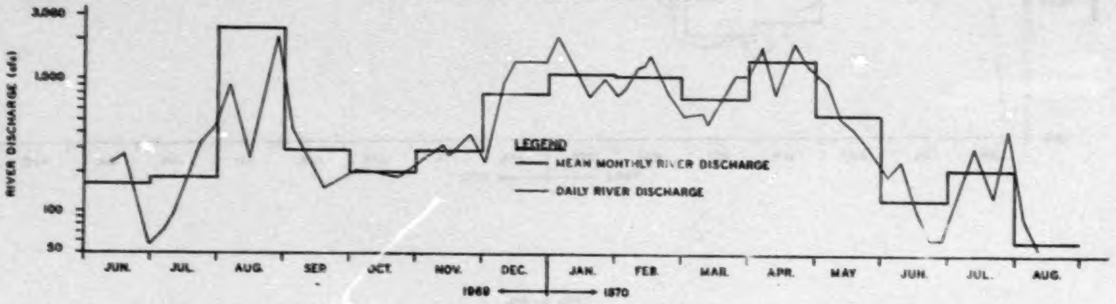
RIVER DISCHARGES (CONTINUED)

(MEAN MONTHLY vs. OBSERVED)

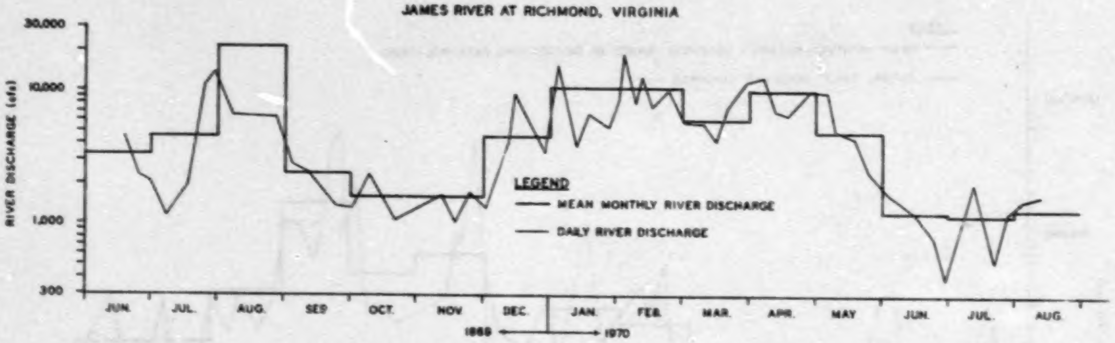
PAMUNKEY RIVER AT HANOVER, VIRGINIA



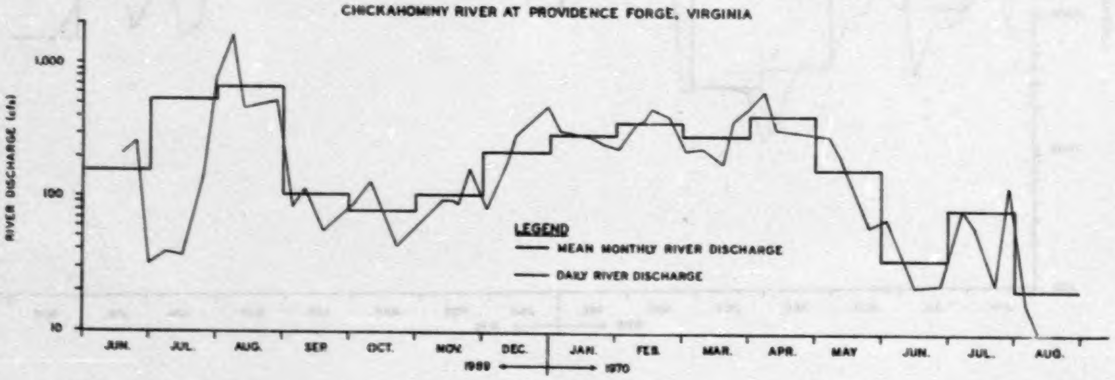
MATTAPONI RIVER AT BEULAHVILLE, VIRGINIA



JAMES RIVER AT RICHMOND, VIRGINIA



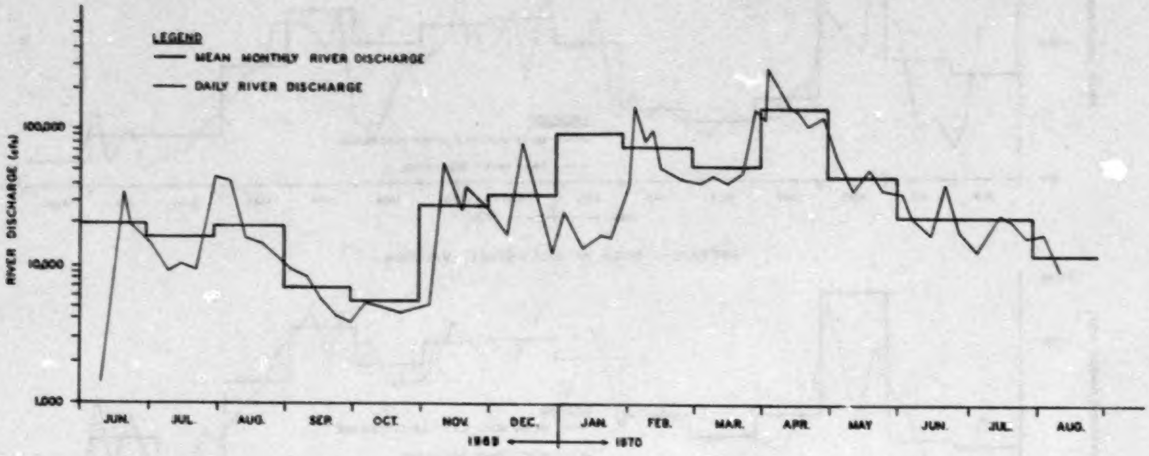
CHICKAHOMINY RIVER AT PROVIDENCE FORGE, VIRGINIA

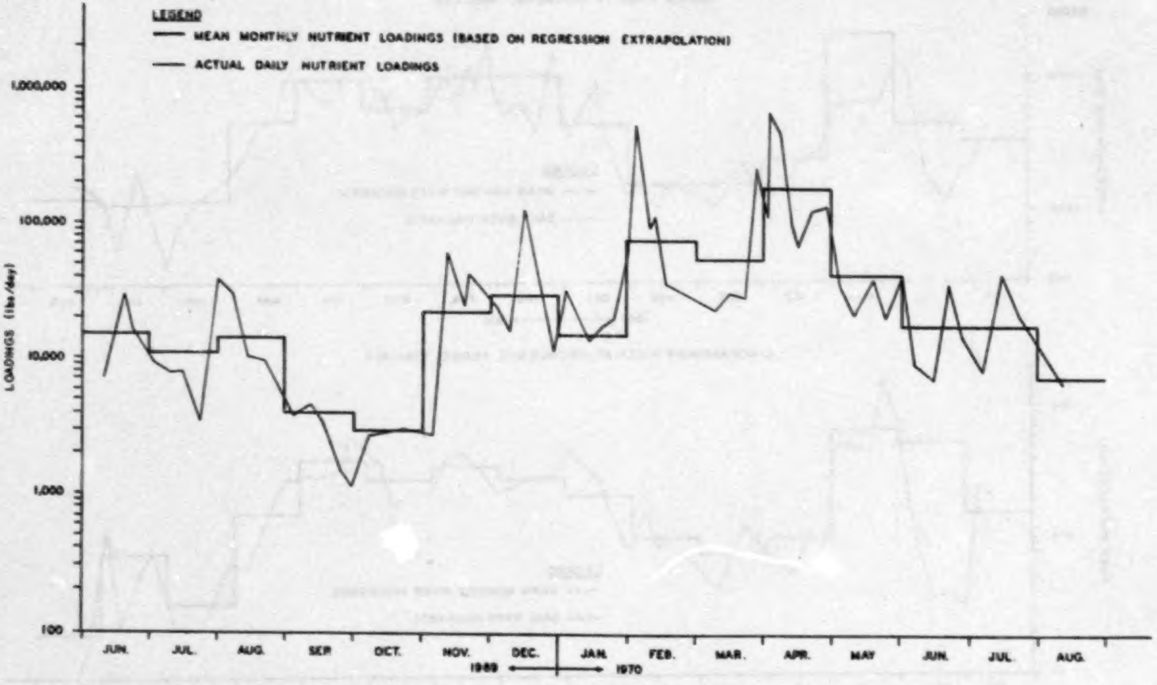


V-61.

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

MEAN MONTHLY NUTRIENT LOADINGS (REGRESSION) vs. ACTUAL DAILY NUTRIENT LOADINGS (OBSERVED)

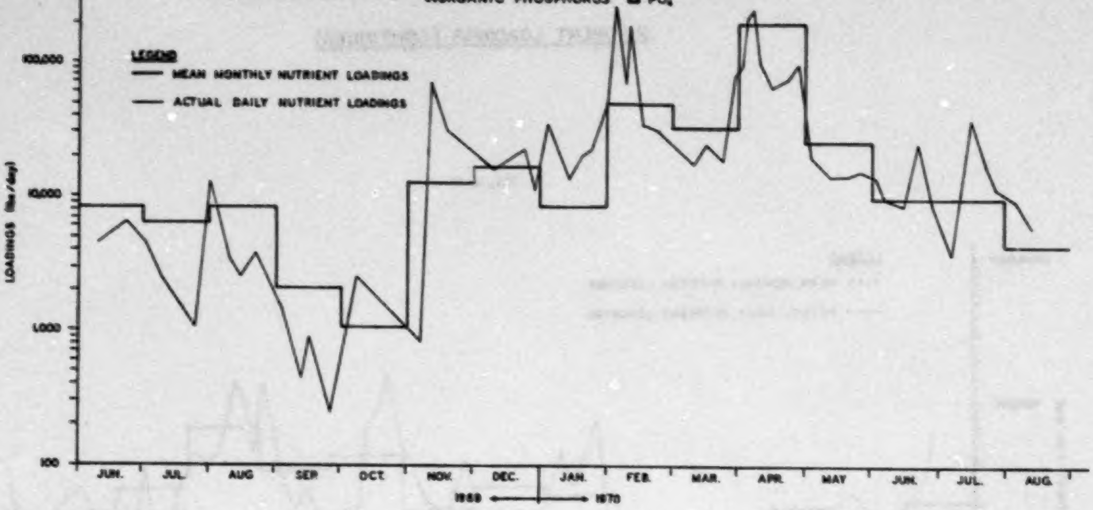

RIVER DISCHARGE


TPO_4 as PO_4

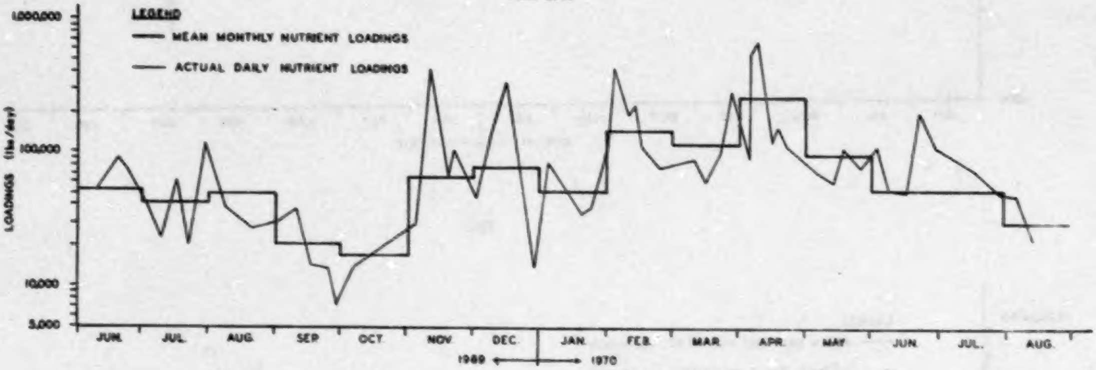
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

NUTRIENT LOADINGS (CONTINUED)

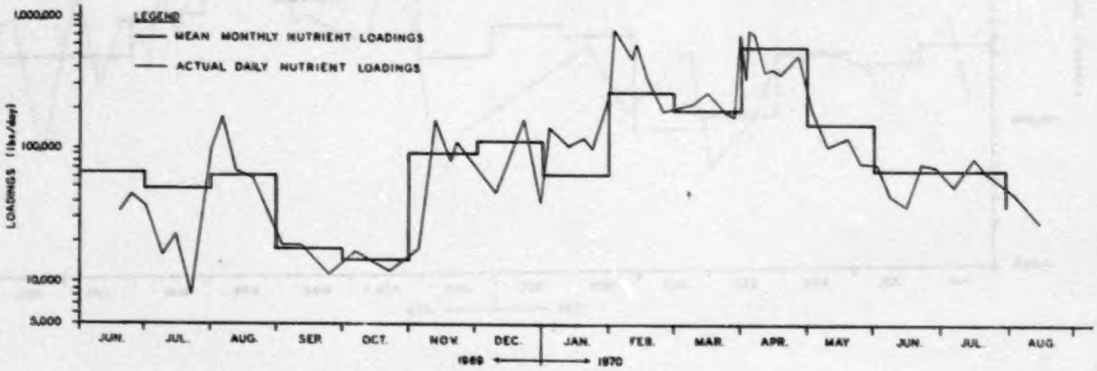
INORGANIC PHOSPHORUS as PO_4



TKN as N



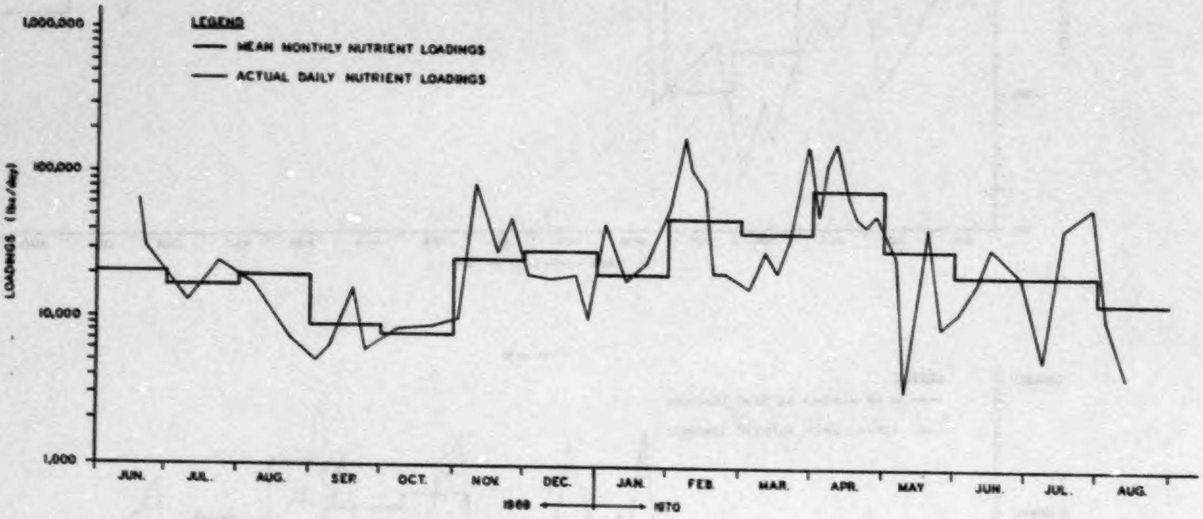
$NO_2 + NO_3$ as N



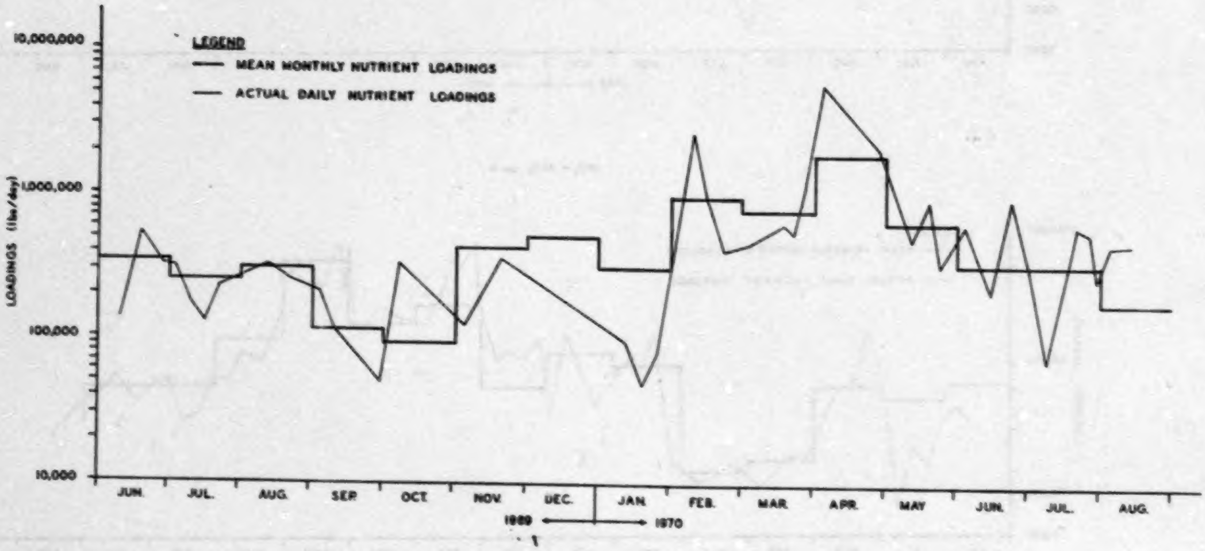
SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

NUTRIENT LOADINGS (CONTINUED)

NH_3 as N



T.O.C.



The following STATPAC codes are utilized for the data presented in the Appendix to indicate parameter irregularities:

Code	Description
N	Not detected, looked for not found, or less than some indefinite lower limit of analytical sensitivity.
H	Interference in the analysis.
L	Concentration is less than some stated lower limit of analytical sensitivity.
G	Concentration greater than some stated upper limit of sensitivity.
B	No data - blank.
T	Trace, concentration is near the lower limit of sensitivity.

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3. Jaworski, N. A., L. J. Clark, and K. D. Feigner, "A Water Resource-Water Supply Study of the Potomac Estuary," Technical Report No. 35, CTSL, WQO, EPA, April 1971.

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6. Chesapeake Bay-Susquehanna River Basin Project, "Water Quality and Pollution Control Study-Patuxent River Basin," Working Document No. 15, MAR, FWPCA, U. S. Department of the Interior, May 1967.

7. Chesapeake Bay-Susquehanna River Basin Project, "Water Quality and Pollution Control Study-Potomac River Basin," Working Document No. 17, MAR, FWPCA, U. S. Department of the Interior, June 1967.

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12. Philadelphia Electric Company, Interim Report,"Thermal Effects on Conowingo Pond Resulting from the Operation of Two New Nuclear Generating Units at Peach Bottom Atomic Power Station, York County, Pennsylvania," January 1968.

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APPENDIX

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D0039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                              DATE  12/17/71
                                                 CHESAPEAKE BAY NUTRIENT INPUT
 SAMPLE        J DATE       TIME        TEMP      FLOW          TPO4       PI        TKN       NO2&NO3      NH3        TOC

061169CW       162.00       0.0 M       0.0 M   13100.00        0.10      0.06      0.89       0.0 B      0.0 M      1.87
061969CW       170.00       0.0 M      26.00    34800.00        0.16      0.03      0.55       0.22       0.35       2.92
062369CW       174.00    1150.00       24.50    18800.00        0.16      0.06      0.89       0.55       0.31       3.43
070269CW       183.00    1035.00       26.50    13300.00        0.13      0.06      0.70       0.64       0.24       4.55
070969CW       190.00     955.00       26.00     8600.00        0.17      0.05      0.56       0.42       0.29       3.79
071569CW       196.00    1150.00       27.50     9600.00        0.15      0.0 M     1.42       0.57       0.35       2.56
072269CW       203.00    1155.00       26.50     8900.00        0.07      0.02      0.50       0.20       0.50       4.72
073069CW       211.00    1155.00       26.00    41100.00        0.18      0.06      0.67       0.57       0.32       0.0 M
080669CW       218.00    1155.00       27.00    31600.00        0.18      0.02      0.27       1.18       0.10       0.0 B
081369CW       225.00    1155.00       26.00    14800.00        0.13      0.03      0.53       1.05       0.0 T      4.14
082069CW       232.00    1235.00       27.00    13800.00        0.13      0.05      0.44       1.05       0.10       3.46
090369CW       246.00    1310.00       25.00     8800.00        0.08      0.03      0.76       0.48       0.11       4.57
091069CW       253.00    1310.00       26.50     7700.00        0.11      0.01      1.12       0.58       0.16       2.66
091769CW       260.00    1225.00       25.50     5200.00        0.12      0.03      0.65       0.63       0.58       0.0 B
092469CW       267.00    1255.00       22.00     4000.00        0.07      0.01      0.80       0.65       0.28       0.0 B
092969CW       272.00    1120.00       20.00     3600.00        0.06      0.0 B     0.44       0.0 B      0.0 B      2.53
100669CW       279.00    1215.00       22.50     5660.00        0.09      0.08      0.57       0.66       0.27      11.40
102269CW       295.00    1405.00       18.00     4300.00        0.14      0.06      1.04       0.65       0.37       0.0 B
110469CW       308.00    1325.00       13.00     4900.00        0.11      0.03      1.34       0.79       0.39       4.80
111169CW       315.00    1505.00       10.50    54200.00        0.22      0.22      1.86       0.73       0.31       0.0 B
111969CW       323.00    1310.00        7.50    23500.00        0.18      0.18      0.61       0.73       0.22       0.0 B
112469CW       328.00    1420.00        5.00    35600.00        0.24      0.22      0.68       0.67       0.26       1.90
120169CW       335.00    1435.00        4.00    22000.00        0.21      0.16      0.43       0.82       0.17       0.0 B
120969CW       343.00    1435.00        2.00    15600.00        0.19      0.19      1.41       0.71       0.23       0.0 B
121569CW       349.00    1440.00        2.50    79300.00        0.31      0.0 B     0.95       0.0 B      0.0 B      0.0 B
122269CW       357.00    1530.00        1.00    29900.00        0.16      0.13      0.36       1.28       0.13       0.0 M
122969CW       363.00    1305.00        2.00    11300.00        0.19      0.18      0.27       0.73       0.17       0.0 B
010570CW       370.00    1405.00       -0.50    23300.00        0.26      0.26      0.83       1.53       0.39       0.0 M
011270CW       377.00    1355.00        1.00    12500.00        0.20      0.20      0.96       1.91       0.29       1.45
011970CW       384.00    1050.00        0.50    15700.00        0.21      0.21      0.49       1.71       0.30       0.60
012670CW       391.00    1340.00        1.00    15200.00        0.24      0.24      0.59       1.49       0.44       1.00
020270CW       398.00    1405.00        1.00    37800.00        0.33      0.23      0.67       1.54       0.31       3.14
020470CW       400.00    1320.00        0.0    147100.00        0.65      0.36      0.66       1.49       0.23       3.95
020970CW       405.00    1325.00        0.0     74400.00        0.19      0.16      0.57       1.42       0.27       2.40
021270CW       408.00    1240.00        0.0     95200.00        0.23      0.23      0.52       1.56       0.17       0.0 M
021670CW       412.00       0.0 B       1.00    48300.00        0.14      0.12      0.48       1.68       0.08       0.0 B
022470CW       420.00    1245.00        2.00    39500.00        0.15      0.13      0.46       1.11       0.10       2.01
030270CW       426.00    1245.00        2.50    35700.00        0.14      0.11      0.16       1.48       0.09       2.40
030970CW       433.00    1100.00        3.00    43200.00        0.10      0.07      0.46       1.40       0.14       2.46
031670CW       440.00    1150.00        4.00    36000.00        0.16      0.12      0.38       1.27       0.12       3.54
032370CW       447.00    1220.00        5.00    44100.00        0.12      0.07      0.52       0.99       0.16       2.37
033070CW       454.00    1120.00        6.50   138100.00        0.35      0.10      0.49       1.21       0.25       2.09
040170CW       456.00    1115.00        5.00   106600.00        0.18      0.15      0.19       0.80       0.09       0.0 B
040370CW       458.00    1035.00        5.00   264600.00        0.48      0.15      0.49       1.01       0.09       4.79
040670CW       461.00    1150.00        6.00   202500.00        0.40      0.20      0.77       0.83       0.16       0.0 B
041370CW       468.00     950.00        8.00   138000.00        0.11      0.11      0.19       0.64       0.10       0.0 B
041570CW       470.00    1035.00        8.00   126600.00        0.09      0.09      0.24       0.73       0.08       0.0 M
042070CW       475.00    1245.00       11.50    97700.00        0.23      0.13      0.28       0.86       0.09       0.0 B
042770CW       482.00    1020.00       13.00   114600.00        0.20      0.15      0.0 T      0.98       0.09       3.71
050470CW       489.00    1250.00       18.00    56300.00        0.12      0.05      0.32       0.80       0.10       0.0 M
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D0019 PUBLICATION LISTING - USGS STATPAC (11/19/71)

DATE 12/17/71

CHESAPEAKE BAY NUTRIENT INPUT

SAMPLE	J DATE	TIME	TEMP	FLOW	TPO4	PI	TKN	NO2&NO3	NH3	TOC
051170CW	496.00	1135.00	18.00	31200.00	0.12	0.06	0.46	0.77	0.02	3.11
051970CW	504.00	1220.00	21.00	48900.00	0.15	0.05	0.53	0.57	0.19	3.59
052570CW	510.00	1205.00	21.00	32600.00	0.11	0.08	0.57	0.56	0.05	1.85
060170CW	517.00	1235.00	20.00	31900.00	0.27	0.07	0.80	0.58	0.07	3.98
060870CW	524.00	1435.00	23.00	21000.00	0.08	0.08	0.60	0.48	0.17	0.0 B
061570CW	531.00	1225.00	24.00	15300.00	0.08	0.08	0.81	0.55	0.41	2.68
062270CW	538.00	1455.00	24.50	35300.00	0.18	0.13	1.46	0.50	0.52	5.58
062970CW	545.00	1500.00	26.50	16400.00	0.16	0.09	1.61	1.03	0.25	4.80
070670CW	552.00	1225.00	22.50	11300.00	0.13	0.06	0.15	1.00	0.09	1.29
071670CW	562.00	1105.00	26.00	20900.00	0.39	0.34	0.85	0.96	0.41	5.85
072070CW	566.00	1220.00	25.00	18900.00	0.22	0.16	0.77	0.0 B	0.0 B	5.40
072870CW	574.00	1500.00	26.00	14400.00	0.19	0.13	0.83	1.09	0.83	3.71
080470CW	581.00	1235.00	29.50	17200.00	0.10	0.10	0.73	0.62	0.12	5.10
081270CW	589.00	925.00	26.50	8400.00	0.14	0.11	0.61	0.84	0.09	10.66
061669GF	167.00	0.0 B	0.0 B	2520.00	0.0 B	0.0 B	0.46	0.05	0.13	0.0 B
070769GF	188.00	0.0 B	0.0 B	598.00	0.53	0.0 B	0.96	0.08	0.70	0.0 B
071469GF	197.00	0.0 B	0.0 B	1860.00	0.58	0.07	0.67	0.04	0.50	0.0 B
072369GF	204.00	0.0 B	0.0 B	4550.00	0.33	0.0 B	0.57	0.29	0.29	7.76
072469GF	205.00	0.0 B	0.0 B	3210.00	0.52	0.06	1.46	0.68	0.48	8.43
072569GF	206.00	0.0 B	0.0 B	2630.00	0.38	0.11	0.89	0.55	0.30	6.91
072669GF	207.00	830.00	0.0 B	3070.00	0.41	0.08	1.29	0.85	0.32	0.0 B
072769GF	208.00	800.00	0.0 B	5080.00	0.64	0.04	1.31	0.51	0.03	0.0 B
072869GF	209.00	800.00	0.0 B	5630.00	0.53	0.09	1.19	0.87	0.22	8.42
072969GF	210.00	800.00	0.0 B	8030.00	0.55	0.09	1.30	0.81	0.17	0.0 B
073069GF	211.00	800.00	0.0 B	7460.00	0.88	0.0 B	1.02	1.29	0.16	6.55
073169GF	212.00	800.00	0.0 B	6580.00	0.65	0.0 B	0.93	1.02	0.06	6.29
080169GF	213.00	800.00	0.0 B	6560.00	0.58	0.0 B	0.72	0.82	0.03	6.29
080469GF	216.00	800.00	0.0 B	10900.00	0.61	0.30	0.92	0.12	0.09	7.43
080569GF	217.00	800.00	0.0 B	13500.00	0.52	0.19	1.01	0.13	0.17	6.81
080669GF	218.00	800.00	0.0 B	13300.00	0.38	0.0 B	1.32	0.95	0.09	7.94
080769GF	219.00	1050.00	0.0 B	10600.00	0.34	0.0 B	0.81	1.03	0.05	0.0 B
080869GF	220.00	0.0 B	0.0 B	9110.00	0.33	0.18	0.77	1.17	0.0 T	7.08
080969GF	221.00	0.0 B	0.0 B	7860.00	0.32	0.12	0.72	0.87	0.0 T	6.51
081069GF	222.00	0.0 B	0.0 B	12600.00	0.34	0.10	0.74	0.90	0.0 T	6.79
082769GF	239.00	1030.00	0.0 B	5420.00	0.29	0.17	0.63	0.96	0.06	4.83
090369GF	246.00	1000.00	27.00	3040.00	0.29	0.05	1.42	0.03	0.08	2.97
090869GF	251.00	800.00	0.0 B	5700.00	0.56	0.0 B	0.72	0.14	0.70	8.30
091069GF	253.00	1030.00	22.00	6800.00	0.68	0.40	1.38	1.38	0.15	5.12
091769GF	260.00	1000.00	23.50	2890.00	0.0 B	0.90	0.80	0.36	0.06	0.0 B
092469GF	267.00	1040.00	20.00	4400.00	0.22	0.02	0.93	0.22	0.03	0.0 B
100669GF	279.00	1215.00	0.0 B	3080.00	0.46	0.10	0.95	0.70	0.10	17.00
102269GF	295.00	1120.00	16.00	1610.00	0.45	0.06	0.83	0.15	0.07	0.0 B
110369GF	307.00	1410.00	14.00	1760.00	0.75	0.07	1.69	0.0 N	0.12	7.30
110469GF	308.00	1050.00	14.00	1770.00	0.25	0.07	0.81	0.10	0.12	10.40
110569GF	309.00	1055.00	11.00	2290.00	0.23	0.08	1.08	0.20	0.25	6.50
110669GF	310.00	1140.00	11.00	3820.00	0.41	0.11	3.21	0.39	0.11	6.90
110769GF	311.00	1130.00	9.00	4070.00	0.49	0.20	0.73	0.92	0.19	0.0 B
111069GF	314.00	1130.00	11.00	4140.00	0.47	0.21	0.50	0.80	0.23	0.0 B
111169GF	315.00	1120.00	11.00	4160.00	0.43	0.22	1.23	1.50	1.30	0.0 B
111269GF	316.00	1120.00	10.00	3800.00	0.73	0.60	0.37	1.04	0.13	8.20

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00039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                    DATE  12/17/71

                                                   CHESAPEAKE BAY NUTRIENT INPUT

 SAMPLE       J DATE       TIME         TEMP      FLOW          TPO4         PI          TKN      NO2&NO3        NH3        TOC

062270GF      538.00     1150.00       24.00     7640.00        1.12        0.86        1.61        1.16        0.45       11.33
062970GF      545.00     1200.00       24.50     8700.00        0.60        0.21        1.78        1.08        0.14        6.73
070670GF      552.00      930.00       25.50     3980.00        0.67        0.16        0.77        0.76        0.02        6.31
071670GF      562.00     1430.00       25.00     7660.00        0.41        0.28        0.57        1.49        0.07        5.99
072070GF      566.00      915.00       27.00     5230.00        0.39        0.12        0.70        0.0 B       0.0 B       4.39
072870GF      574.00        0.0 B       0.0 B    3780.00        0.28        0.15        0.80        0.72        0.55        4.95
080470GF      581.00     1140.00       26.50     5100.00        0.37        0.20        0.65        1.22        0.06        9.58
081270GF      589.00      645.00       25.50     2940.00        0.30        0.17        0.56        0.68        0.02       14.76
090970GF      617.00     1010.00       25.00     1700.00        0.68        0.16        1.15        0.10        0.11       12.25
061269RF      163.00        0.0 B       0.0 B     436.00        0.28        0.03        0.56        1.07        0.20        0.0 B
061869RF      169.00        0.0 B      22.00      992.00        1.08        0.17        0.84        0.90        0.29       11.16
062569RF      176.00     1545.00       28.00      340.00        0.16        0.05        0.29        0.42        0.05        3.74
063069RF      181.00     1500.00       30.50      239.00        0.14        0.04        0.58        0.02        0.0 N       2.91
070769RF      188.00     1600.00       28.50      208.00        0.08        0.03        0.36        0.0 B       0.0 B       3.32
071669RF      197.00     1230.00       27.50      325.00        0.30        0.09        0.78        0.56        0.08        5.50
072369RF      204.00      945.00       27.00      867.00        0.13        0.0 T       0.56        0.15        0.07        0.0 B
073169RF      212.00     1200.00       24.00     2990.00        0.48        0.07        1.12        0.57        0.12        8.95
080769RF      219.00      800.00       23.00     1370.00        0.20        0.06        0.58        0.49        0.03        8.10
081469RF      226.00     1145.00       24.00      592.00        0.15        0.06        0.71        0.38        0.04        4.93
082869RF      240.00     1315.00       24.00      332.00        0.11        0.05        0.36        0.10        0.05        0.0 B
090469RF      247.00     1330.00       26.70      228.00        0.18        0.08        0.74        0.10        0.07        3.20
091169RF      254.00     1355.00       21.00      540.00        0.28        0.12        0.37        0.48        0.07        0.0 B
091869RF      261.00     1230.00       22.00      349.00        0.09        0.04        0.41        0.03        0.05        0.0 B
100269RF      275.00     1325.00       20.00      342.00        0.41        0.28        0.31        0.23        0.06        9.57
100969RF      282.00     1335.00       19.50      582.00        0.14        0.14        0.62        0.0 B       0.0 B       0.0 B
102269RF      295.00     1315.00       16.00      382.00        0.23        0.14        0.93        0.0 N       0.10        0.0 B
111269RF      316.00     1435.00        9.50      760.00        0.14        0.10        0.57        0.14        0.02        4.60
111869RF      322.00     1430.00        6.00      504.00        0.11        0.11        0.28        0.05        0.03        0.0 B
112469RF      328.00     1525.00        5.00      680.00        0.21        0.14        0.27        0.21        0.02        0.0 T
120269RF      336.00     1350.00        3.00      470.00        0.13        0.13        0.30        0.05        0.02        0.0 B
121169RF      345.00     1450.00        5.00     8520.00        0.45        0.32        1.24        0.21        0.09        0.0 B
121569RF      349.00     1450.00        4.50     1900.00        0.32        0.0 B       0.62        0.0 B       0.0 B       0.0 B
122969RF      363.00     1535.00        1.00     1280.00        0.24        0.18        0.45        0.64        0.05        0.0 B
010570RF      370.00     1430.00        0.0      2040.00        0.22        0.17        0.89        1.17        0.28        1.41
011270RF      377.00     1450.00       -1.00     1100.00        0.18        0.10        0.74        1.44        0.08        2.90
011970RF      385.00     1405.00        0.0      6180.00        0.50        0.38        1.03        0.94        0.18        5.70
020270RF      398.00     1220.00        4.50     1850.00        0.14        0.13        0.35        1.08        0.07        1.28
020470RF      400.00     1400.00        3.50     5450.00        0.71        0.41        1.28        0.88        0.81        6.67
020970RF      405.00     1340.00        4.00     2040.00        0.17        0.15        0.47        0.88        0.23        0.0 T
021270RF      408.00     1410.00        5.00     4080.00        0.31        0.31        0.33        1.26        0.12        2.49
021670RF      412.00     1350.00        2.00     2390.00        0.11        0.11        0.49        0.89        0.06        0.0 B
022470RF      420.00     1230.00        5.00     1700.00        0.20        0.12        0.34        0.64        0.04        2.32
030270RF      426.00     1340.00        5.00     1180.00        0.17        0.08        0.0 B       0.99        0.03        1.89
030970RF      433.00     1440.00        8.00     1160.00        0.17        0.06        0.35        0.59        0.06        3.07
031670RF      440.00     1210.00        5.00      940.00        0.15        0.06        0.39        0.54        0.03        2.60
032370RF      447.00     1315.00        7.00     3000.00        0.15        0.07        0.70        0.56        0.08        4.17
033070RF      454.00     1100.00        8.00     3540.00        0.27        0.07        0.55        0.60        0.14        4.36
040770RF      462.00     1335.00        9.50     2420.00        0.11        0.10        0.44        0.61        0.13        0.0 B
041270RF      467.00     1355.00       12.00     1470.00        0.11        0.11        0.34        0.41        0.10        0.0 B
042070RF      475.00      900.00       12.00     1850.00        0.12        0.08        0.15        0.46        0.04        0.0 B
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D0039 PUBLICATION LISTING - USGS STATPAC (11/19/71)
                                                                                         DATE  12/17/71
                                          CHESAPEAKE BAY NUTRIENT INPUT
  SAMPLE       J DATE       TIME        TEMP       FLOW          TPO4       PI        TKN      NO2&NO3      NH3        TOC

 111369GF      317.00     1130.00       9.50     3700.00        0.38     0.0 B      0.18       0.99       0.08       4.89
 111469GF      318.00     1030.00      10.00     3730.00        0.44     0.26       1.05       0.99       0.10       6.40
 111769GF      321.00     1130.00       0.0 B    3410.00        0.45     0.26       1.88       0.96       0.19       0.0 B
 111869GF      322.00     1200.00       7.00     3360.00        0.44     0.22       0.97       1.02       0.06       0.0 B
 111969GF      323.00      955.00       9.00     3330.00        0.39     0.29       0.96       1.02       0.13       0.0 B
 112169GF      325.00     1130.00       5.00     4670.00        0.27     0.27       0.88       1.61       0.27       0.60
 112469GF      328.00     1030.00       7.00     4330.00        0.39     0.39       0.76       1.16       0.12       2.90
 120169GF      335.00     1055.00       5.00     3290.00        0.27     0.24       0.35       0.99       0.05       0.0 B
 120969GF      343.00     1110.00       4.50     3370.00        0.25     0.25       0.08       0.85       0.08       0.0 B
 121169GF      345.00     1145.00       7.00    12400.00        2.27     0.58       1.75       1.10       0.23       0.0 B
 121269GF      346.00      715.00       5.00    17800.00        0.0 B    0.66       1.38       1.58       0.36       0.0 B
 121569GF      349.00     1045.00       4.00    18700.00        0.29     0.0 B      0.75       0.0 B      0.0 B      0.0 B
 122269GF      356.00     1200.00       3.00     7150.00        0.27     0.19       0.29       2.14       0.07       0.0 B
 010570GF      370.00     1100.00      -1.00    18800.00        0.26     0.26       1.04       1.73       0.29       2.74
 012170GF      387.00     1350.00       0.0      5850.00        0.26     0.17       0.59       1.45       0.28       3.21
 012670GF      391.00     1000.00       0.0 B    6920.00        0.22     0.22       0.38       1.69       0.28       0.0 T
 020270GF      398.00     1020.00       2.50    29400.00        0.30     0.30       1.35       1.60       0.19      11.05
 020470GF      400.00     1100.00       1.00    36000.00        1.76     0.79       1.34       1.58       0.21       9.15
 020970GF      405.00     1015.00       4.00    15600.00        0.26     0.15       0.22       1.96       0.22       1.50
 021270GF      408.00     1010.00       2.00    30100.00        0.39     0.32       0.22       1.95       0.11       1.00
 021670GF      412.00     1125.00       0.0 B   13900.00        0.17     0.16       0.51       2.25       0.07       0.0 B
 022470GF      420.00      945.00       5.00    16000.00        0.23     0.14       0.49       1.35       0.06       2.66
 030270GF      426.00      950.00       5.00    11100.00        0.18     0.13       0.0 B      1.69       0.05       2.08
 030970GF      433.00      805.00       6.00    18900.00        0.18     0.10       0.71       1.33       0.08       3.99
 031670GF      440.00      930.00       4.00    11400.00        0.29     0.18       0.46       1.53       0.06       2.22
 032370GF      447.00      930.00       6.00    28000.00        0.52     0.17       0.79       1.15       0.12       4.92
 033070GF      454.00      900.00       6.50    21900.00        0.35     0.11       0.43       1.49       0.19       2.81
 040170GF      456.00      850.00       6.00    25400.00        0.20     0.15       0.33       1.30       0.07       0.0 B
 040270GF      457.00        0.0 B      0.0 B   35600.00        0.41     0.11       0.59       1.28       0.15       6.07
 040370GF      458.00        0.0 B      0.0 B   77300.00        1.31     0.36       2.06       1.09       0.27       7.08
 040470GF      459.00        0.0 B      0.0 B   85700.00        1.44     0.32       2.53       0.92       0.26       0.0 B
 040570GF      460.00        0.0 B      0.0 B   57000.00        0.96     0.28       1.49       1.03       0.20       0.0 B
 040670GF      461.00        0.0 B      0.0 B   41600.00        0.49     0.19       0.72       1.28       0.11       0.0 B
 040770GF      462.00        0.0 B      0.0 B   33600.00        0.40     0.20       0.49       1.43       0.10       0.0 B
 040870GF      463.00      800.00       0.0 B   27900.00        0.32     0.18       0.36       1.51       0.10       0.0 B
 040970GF      464.00      800.00       0.0 B   24100.00        0.33     0.18       0.26       1.54       0.10       0.0 B
 041070GF      465.00      800.00       0.0 B   21100.00        0.28     0.13       0.12       1.48       0.10       0.0 B
 041170GF      466.00     1100.00       0.0 B   18800.00        0.33     0.18       0.10       1.48       0.10       0.0 B
 041270GF      467.00      700.00       0.0 B   17500.00        0.32     0.20       0.10       1.39       0.10       0.0 B
 041370GF      468.00        0.0 B      0.0 B   16000.00        0.49     0.17       0.25       1.41       0.10       0.0 B
 041570GF      470.00     1330.00       9.50    41000.00        0.74     0.38       1.74       1.24       0.20       0.0 B
 042070GF      475.00      930.00      12.50    23500.00        0.31     0.14       0.49       1.47       0.07       0.0 B
 042770GF      482.00     1240.00      14.00    43800.00        0.60     0.22       0.19       0.97       0.04       4.85
 050470GF      489.00      930.00      19.00    16000.00        0.37     0.05       0.48       1.28       0.02       0.0 B
 051170GF      496.00      855.00      22.00     8720.00        0.25     0.10       0.59       1.03       0.02       5.32
 051970GF      504.00      845.00      20.00     7970.00        0.24     0.11       0.32       1.44       0.10       4.99
 052570GF      510.00      915.00      22.00     7040.00        2.84     0.42       0.60       0.99       0.60      12.31
 060170GF      517.00      915.00      23.00     4350.00        0.38     0.12       1.23       1.00       0.03       4.84
 060870GF      524.00     1115.00      22.50    10600.00        0.32     0.24       1.10       1.50       0.09       0.0 B
 061570GF      531.00      920.00      23.50     4070.00        0.22     0.22       0.36       1.85       0.0 T      5.01
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6

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00039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                        DATE  12/17/71

                                                    CHESAPEAKE BAY NUTRIENT INPUT

  SAMPLE       J DATE      TIME       TEMP      FLOW        TP04        PI          TKN      NO2&NO3        NH3          TOC

042870RF      483.00    1800.00      16.00    2480.00       0.11       0.09        0.20       0.45         0.02         3.22
050670RF      491.00    1235.00       0.0 B   2020.00       0.22       0.10        0.46       0.49         0.09         0.0 B
051170RF      496.00    1115.00      21.50    1200.00       0.15       0.09        0.38       0.29         0.06         3.27
051870RF      503.00    1400.00      19.00    1880.00       0.16       0.10        0.40       0.50         0.02         4.87
052570RF      510.00    1130.00      23.50    2860.00       2.31       0.36        1.09       0.89         0.41         8.53
060270RF      518.00     915.00      23.00     600.00       0.16       0.11        0.46       0.50         0.06         0.0 B
060970RF      525.00    1430.00      25.00     624.00       0.13       0.13        0.38       0.86         0.0 T        0.0 B
061670RF      532.00    1320.00      23.50     430.00       0.09       0.09        0.65       0.22         0.10         4.15
062370RF      539.00    1350.00      28.00     398.00       0.14       0.05        0.10       0.15         0.10         2.19
062970RF      545.00    1845.00      24.50     430.00       0.07       0.07        0.39       0.0 T        0.02         2.19
070670RF      552.00    1345.00      28.00     414.00       0.05       0.05        0.36       0.05         0.02         1.25
071370RF      559.00    1400.00      26.00     696.00       0.24       0.24        0.88       0.63         0.12         5.20
072170RF      567.00    1400.00      27.00     256.00       0.19       0.13        1.16       0.23         0.04         4.75
072770RF      573.00    1405.00      27.00     632.00       0.24       0.22        0.67       0.55         0.09         5.99
080470RF      581.00    1420.00      27.00     984.00       0.23       0.23        0.52       0.39         0.02         7.14
081170RF      588.00    1350.00      24.00     426.00       0.37       0.37        1.14       0.55         0.05        16.52
061269PH      163.00       0.0 B      0.0 B   1330.00       0.27       0.03        0.66       0.28         0.18         0.0 B
061869PH      169.00       0.0 B     21.50    1360.00       0.29       0.13        0.59       0.20         0.27        14.54
062569PH      176.00    1435.00      26.00     253.00       0.15       0.05        0.54       0.20         0.09         8.64
063069PH      181.00    1400.00      28.00     163.00       0.18       0.11        0.25       0.10         0.06         6.28
070769PH      188.00    1400.00      26.00     285.00       0.19       0.0 N       0.41       0.0 B        0.0 B        7.95
071669PH      197.00    1115.00      25.00     237.00       0.16       0.05        0.41       0.19         0.03         6.00
072369PH      204.00    1345.00      24.50    1400.00       0.0 B      0.84        1.26       0.15         0.15         0.0 B
073169PH      212.00    1100.00      23.50    1690.00       0.48       0.05        1.07       0.22         0.10        17.70
080769PH      219.00    1130.00      22.00    3440.00       0.25       0.04        0.70       0.11         0.05        15.33
081469PH      226.00    1030.00      23.00     850.00       0.17       0.07        0.61       0.15         0.03         9.52
082869PH      240.00    1030.00      21.00    1980.00       0.19       0.04        0.38       0.15         0.06         0.0 B
090469PH      247.00    1200.00      23.00     487.00       0.15       0.05        0.55       0.25         0.05         5.98
091169PH      254.00    1250.00      20.00     465.00       0.11       0.06        0.32       0.10         0.03         0.0 B
091869PH      261.00    1130.00      20.50     285.00       0.10       0.04        0.36       0.12         0.11         0.0 B
100269PH      275.00    1220.00      16.00     275.00       0.13       0.11        0.30       0.70         0.10         5.06
100969PH      282.00    1000.00      18.00     328.00       0.15       0.15        0.26       0.0 B        0.0 B        0.0 B
102269PH      295.00     925.00      15.00     212.00       0.54       0.13        0.56       0.05         0.07         0.0 B
111269PH      316.00    1015.00       9.00     383.00       0.15       0.12        0.40       0.04         0.02         6.20
111869PH      322.00    1035.00       5.50     278.00       0.16       0.16        0.99       0.05         0.03         0.0 B
112469PH      328.00    1110.00       5.00     430.00       0.17       0.17        0.46       0.09         0.04         2.20
120269PH      336.00    1010.00       7.00     284.00       0.15       0.15        0.39       0.09         0.02         0.0 B
121169PH      345.00    1050.00       5.50    1850.00       0.32       0.23        0.91       0.09         0.26         0.0 B
121569PH      349.00    1040.00       4.00     950.00       0.25       0.0 B       0.48       0.0 B        0.0 B        0.0 B
122969PH      363.00    1125.00       1.00    1000.00       0.16       0.15        0.14       0.24         0.05         0.0 B
010570PH      370.00    1150.00       1.00    2600.00       0.26       0.25        0.51       0.51         0.05         3.91
011270PH      377.00    1040.00       0.0      540.00       0.11       0.11        0.55       0.39         0.08         1.18
011970PH      384.00    1020.00       0.0     1890.00       0.22       0.22        0.48       0.29         0.11         3.20
012670PH      391.00    1015.00       1.00    1070.00       0.14       0.14        0.69       0.41         0.54         1.70
020270PH      398.00     940.00       4.00     983.00       0.13       0.13        0.40       0.30         0.07         4.44
020470PH      400.00    1020.00       4.00    1340.00       0.24       0.24        0.66       0.24         0.39         6.60
020970PH      405.00    1015.00       3.00    1140.00       0.17       0.15        0.33       0.35         0.28         2.80
021270PH      408.00    1025.00       4.50    3500.00       0.36       0.36        0.48       0.35         0.09         4.07
021670PH      412.00    1015.00       4.00    1100.00       0.13       0.11        0.47       0.28         0.05         0.0 B
022470PH      420.00     930.00       5.00     965.00       0.15       0.15        0.46       0.19         0.03         5.20
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7

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00039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                         DATE   12/17/71

                                                    CHESAPEAKE BAY NUTRIENT INPUT
  SAMPLE       J DATE      TIME        TEMP       FLOW          TPO4          PI          TKN       NO2&NO3       NH3        TOC

 030270PH      426.00     955.00       5.00      723.00         0.13         0.08        0.0 B       0.22         0.04       3.26
 030970PH      433.00    1050.00       8.00      735.00         0.10         0.06        0.48        0.16         0.05       4.87
 031670PH      440.00     940.00       5.00      600.00         0.09         0.07        0.52        0.12         0.04       2.33
 032370PH      447.00     940.00       7.00     2010.00         0.11         0.09        0.47        0.22         0.06       6.07
 033070PH      454.00     820.00       8.00     3050.00         0.81         0.13        0.73        0.25         0.19       9.82
 040770PH      462.00    1020.00       9.00     1930.00         0.11         0.11        0.47        0.22         0.15       0.0 B
 041270PH      467.00    1105.00      12.50      973.00         0.11         0.11        0.10        0.11         0.10       0.0 B
 042070PH      475.00    1230.00      14.00     1330.00         0.14         0.09        0.24        0.15         0.04       0.0 B
 042870PH      483.00    1630.00      15.50     1610.00         0.35         0.20        0.32        0.12         0.11       7.09
 050670PH      491.00     930.00       0.0 B    1520.00         0.25         0.13        0.42        0.21         0.17       0.0 B
 051170PH      496.00     835.00      20.00      673.00         0.11         0.11        0.36        0.13         0.02       5.97
 051870PH      503.00     945.00      17.00      648.00         0.12         0.11        0.35        0.20         0.02       5.50
 052570PH      510.00     905.00      23.50      450.00         0.14         0.12        0.38        0.22         0.0 T      3.45
 060270PH      518.00    1305.00      23.00      339.00         0.12         0.11        1.13        0.24         0.07       0.0 B
 060970PH      525.00    1310.00      23.50      271.00         0.11         0.11        0.54        0.17         0.0 T      0.0 B
 061670PH      532.00    1220.00      22.00      180.00         0.08         0.08        0.26        0.02         0.10       5.54
 062370PH      539.00    1240.00      26.00      162.00         0.14         0.05        0.41        0.04         0.10       5.07
 062970PH      545.00    1655.00      23.00      153.00         0.09         0.08        0.62        0.04         0.02       2.70
 070670PH      552.00    1220.00      25.00      125.00         0.09         0.07        0.49        0.06         0.02       3.59
 071370PH      559.00    1240.00      26.00      256.00         0.16         0.16        0.79        0.20         0.09       5.20
 072170PH      567.00    1245.00      24.00      137.00         0.07         0.07        1.25        0.08         0.03       3.39
 072770PH      573.00    1255.00      26.00      366.00         0.27         0.27        0.95        0.26         0.08       9.18
 080470PH      581.00    1320.00      28.00      150.00         0.13         0.13        0.0 B       0.11         1.54       7.75
 081170PH      588.00    1045.00      22.50      145.00         0.10         0.10        0.63        0.07         0.02      10.72
 061269MB      163.00       0.0 B      0.0 B     236.00         0.13         0.11        0.39        0.14         0.05       0.0 B
 061869MB      169.00       0.0 B     21.00      281.00         0.10         0.10        0.41        0.12         0.10      10.81
 062569MB      176.00    1500.00      26.00      118.00         0.14         0.07        0.68        0.09         0.06       9.78
 063069MB      181.00    1430.00      28.00       56.00         0.08         0.06        0.51        0.05         0.06       7.54
 070769MB      188.00    1510.00      26.50       73.00         0.12         0.06        0.53        0.0 B        0.0 B      7.70
 071669MB      197.00    1135.00      25.00       93.00         0.19         0.11        0.84        0.17         0.06      10.20
 072369MB      204.00    1400.00      26.00      321.00         0.48         0.23        0.90        0.08         0.08       0.0 B
 073169MB      212.00    1115.00      23.50      447.00         0.27         0.15        0.88        0.09         0.06      14.70
 080769MB      219.00    1145.00      23.00      949.00         0.25         0.08        0.90        0.03         0.04      21.00
 081469MB      226.00    1045.00      23.00      251.00         0.29         0.14        0.72        0.18         0.05      11.59
 082869MB      240.00    1230.00      20.00     2160.00         0.19         0.09        0.64        0.12         0.10       0.0 B
 090469MB      247.00    1230.00      23.00      410.00         0.23         0.12        0.70        0.30         0.07       8.76
 091169MB      254.00    1310.00      19.50      262.00         0.20         0.15        0.31        0.21         0.06       0.0 B
 091869MB      261.00    1150.00      20.50      150.00         0.16         0.10        0.48        0.15         0.05       0.0 B
 100269MB      275.00    1240.00      15.50      210.00         0.18         0.13        0.43        0.13         0.08       0.0 B
 100969MB      282.00    1000.00      18.00      200.00         0.21         0.19        0.0 T       0.0 B        0.0 B      0.0 B
 102269MB      295.00     910.00      15.00      180.00         0.19         0.16        0.0 B       0.02         0.07       0.0 B
 111269MB      316.00     955.00       9.00      328.00         0.18         0.15        0.73        0.02         0.02       9.50
 111569MB      322.00    1020.00       5.50      261.00         0.23         0.15        0.25        0.03         0.04       0.0 B
 112469MB      328.00    1040.00       5.00      397.00         0.13         0.13        0.52        0.02         0.03       3.90
 120269MB      336.00     950.00       7.00      237.00         0.16         0.16        0.14        0.04         0.09       0.0 B
 121169MB      345.00    1035.00       2.50      924.00         0.0 B        0.54        3.70        0.41         0.15       0.0 B
 121569MB      349.00    1020.00       4.00     1330.00         0.20         0.0 B       0.53        0.0 B        0.0 B      0.0 B
 122469MB      363.00    1050.00       1.00     1340.00         0.13         0.13        0.06        0.10         0.03       0.0 B
 010570MB      370.00    1035.00       0.0      2090.00         0.19         0.19        0.0 B       0.18         0.07       6.32
 011470MB      384.00    1000.00       0.0       720.00         0.16         0.15        0.22        0.20         0.08       6.20
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00039 PUBLICATION LISTING - USGS STATPAC (11/14/71)                                                    DATE  12/17/71

                                          CHESAPEAKE BAY NUTRIENT INPUT

 SAMPLE      J DATE      TIME       TEMP      FLOW        TPO4       PI        TKN      NO2&NO3       NH3       TOC

012670MB    341.00     950.00      1.00    1000.00       0.12      0.12       0.49       0.20       0.16       2.90
020270MB    348.00     915.00      4.00     746.00       0.16      0.16       0.10       0.13       0.10       5.93
020470MB    400.00    1000.00      4.00     870.00       0.0 B     0.20       0.65       0.11       0.05       4.94
020970MB    405.00     950.00      3.00    1210.00       0.11      0.11       0.45       0.17       0.20       3.40
021270MB    408.00    1010.00      4.00    1270.00       0.17      0.17       0.35       0.12       0.15       1.93
021670MB    412.00    1000.00      3.00    1510.00       0.09      0.08       0.42       0.15       0.06       0.0 B
022470MB    420.00     920.00      5.00     792.00       0.16      0.13       0.84       0.08       0.04       4.72
030270MB    426.00     930.00      5.00     523.00       0.10      0.08       0.0 B      0.11       0.07       4.08
030970MB    433.00    1025.00      8.00     586.00       0.06      0.05       0.52       0.05       0.05       5.47
031670MB    440.00     920.00      5.00     479.00       0.09      0.08       0.32       0.07       0.03       4.55
032370MB    447.00     915.00      8.00    1070.00       0.08      0.07       0.33       0.10       0.06       7.54
033070MB    454.00     800.00      8.00    1090.00       0.14      0.07       0.37       0.13       0.10       6.98
040770MB    462.00     945.00      9.00    1810.00       0.10      0.10       0.29       0.07       0.12       0.0 B
041270MB    467.00    1050.00     12.00     797.00       0.09      0.09       0.28       0.03       0.10       0.0 B
042070MB    475.00    1245.00     14.00    1910.00       0.12      0.09       0.30       0.05       0.04       0.0 B
042870MB    483.00    1650.00     16.50    1260.00       0.18      0.18       0.57       0.05       0.05       9.28
050670MB    491.00     900.00      0.0 B    917.00       0.14      0.14       0.44       0.18       0.12       0.0 B
051170MB    496.00     815.00     20.00     495.00       0.15      0.13       0.48       0.10       0.03       9.57
051870MB    503.00     925.00     17.00     422.00       0.22      0.12       0.55       0.16       0.06      11.87
052570MB    510.00     850.00     23.00     310.00       0.22      0.17       0.51       0.19       0.02       3.45
060270MB    518.00    1320.00     22.00     190.00       0.22      0.17       0.84       0.18       0.07       0.0 B
060970MB    525.00    1330.00     22.50     250.00       0.15      0.14       0.42       0.14       0.0 T      0.0 B
061670MB    532.00    1240.00     22.00     100.00       0.11      0.11       0.63       0.06       0.10       9.09
062370MB    539.00    1300.00     26.00      67.00       0.21      0.11       0.44       0.05       0.10       8.28
062970MB    545.00    1710.00     22.50      65.00       0.16      0.12       0.61       0.09       0.02       6.20
070670MB    552.00    1240.00     24.50     170.00       0.14      0.11       0.71       0.11       0.02       6.61
071370MB    559.00    1300.00     25.00     316.00       0.15      0.15       0.58       0.16       0.09       7.28
072170MB    567.00    1310.00     23.00     128.00       0.20      0.15       1.12       0.08       0.03       5.85
072770MB    573.00    1315.00     25.00     424.00       0.19      0.19       0.81       0.14       0.11      11.06
080470MB    581.00    1335.00     29.00      90.00       0.17      0.17       0.40       0.14       0.06      17.17
081170MB    588.00    1025.00     23.00      57.00       0.18      0.17       0.87       0.04       0.03      13.17
061869JR    169.00       0.0 B     0.0 B   4450.00       0.19      0.15       0.38       0.63       0.27       5.69
062569JR    176.00    1230.00     28.00    2330.00       0.15      0.05       0.43       0.81       0.04       6.26
063069JR    181.00    1150.00     31.00    2110.00       0.09      0.03       0.44       1.10       0.09       6.43
070769JR    188.00    1203.00     29.50    1140.00       0.10      0.0 T      0.41       0.0 B      0.0 B      7.73
071669JR    197.00     930.00     27.50    1920.00       0.25      0.09       0.43       0.63       0.06       5.50
072369JR    204.00    1155.00     25.00   10100.00       0.0 B     0.72       1.99       0.19       0.19       0.0 B
073169JR    212.00     915.00     24.50   14000.00       0.96      0.03       1.42       0.37       0.10      15.60
080769JR    219.00     940.00     24.00    6480.00       0.37      0.06       0.86       0.65       0.04       9.77
081469JR    226.00     845.00     25.00    6320.00       0.17      0.06       0.86       0.62       0.03       4.78
082869JR    240.00    1030.00     23.50    6320.00       0.18      0.06       0.44       0.52       0.10       0.0 B
090469JR    247.00    1015.00     26.00    2820.00       0.19      0.0 T      1.11       0.25       0.04       4.80
091169JR    254.00       0.0 B    23.00    2520.00       0.11      0.02       0.64       0.22       0.03       0.0 B
091869JR    261.00    1000.00     24.00    1400.00       0.14      0.14       0.64       0.74       0.06       5.17
100269JR    275.00    1025.00     20.00    1370.00       0.11      0.10       0.23       0.63       0.06       0.0 B
100969JR    282.00    1040.00     20.00    2280.00       0.13      0.13       0.15       0.0 B      0.0 B      0.0 B
102269JR    295.00    1000.00     14.50    1050.00       0.19      0.12       0.75       0.96       0.14       0.0 B
111269JR    316.00    1055.00     10.50    1690.00       0.26      0.15       0.64       1.07       0.10       7.40
111869JR    322.00    1115.00      8.00    1030.00       0.23      0.16       0.61       1.26       0.11       0.0 B
112469JR    328.00    1150.00      5.00    1760.00       0.26      0.22       0.71       1.04       0.29       3.60
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00039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                     DATE  12/17/71

                                              CHESAPEAKE BAY NUTRIENT INPUT

   SAMPLE       J DATE      TIME       TEMP      FLOW        TPO4       PI        TKN      NO2&NO3      NH3       TOC

   120269JR     336.00    1100.00      5.00    1300.00       0.20      0.20      0.36      1.17       0.10      0.0 B
   121169JR     345.00      0.0 B      0.0 B   4200.00       0.58      0.43      0.78      0.76       0.23      0.0 B
   121569JR     349.00    1120.00      5.00    9530.00       0.20      0.0 B     0.64      0.0 B      0.0 B     0.0 B
   122969JR     363.00    1200.00      2.00    3450.00       0.18      0.16      0.0 H     0.47       0.35      0.0 B
   010570JR     370.00    1130.00      3.00   15400.00       0.25      0.25      0.48      0.56       0.10      4.09
   011270JR     377.00    1115.00      1.00    3800.00       0.13      0.13      0.85      0.80       0.30      1.18
   011970JR     385.00    1100.00      2.00    6980.00       0.22      0.19      0.49      0.73       0.28      0.0 T
   012670JR     391.00    1100.00      1.00    5480.00       0.18      0.17      0.88      0.69       0.55      3.90
   020270JR     398.00    1020.00      5.00    8940.00       0.16      0.16      0.65      0.60       0.39      6.58
   020470JR     400.00    1100.00      5.50   19900.00       0.0 B     0.39      0.68      0.38       0.16     10.11
   020970JR     405.00    1045.00      4.50    8020.00       0.17      0.16      0.50      0.48       0.30      1.07
   021270JR     408.00    1100.00      5.00   12600.00       0.29      0.25      0.68      0.41       0.39      0.91
   021670JR     412.00    1110.00      6.50    7660.00       0.18      0.13      0.52      0.44       0.15      0.0 B
   022470JR     420.00    1015.00      6.50   10500.00       0.27      0.14      0.43      0.28       0.20      2.88
   030270JR     426.00    1035.00      6.50    5850.00       0.17      0.08      1.29      0.51       0.10      2.56
   030970JR     433.00    1145.00      9.00    5850.00       0.13      0.05      0.67      0.68       0.21      4.34
   031670JR     440.00    1020.00      8.00    4200.00       0.16      0.10      0.62      0.66       0.14      3.07
   032370JR     447.00    1030.00      8.00    7660.00       0.18      0.09      0.63      0.54       0.18      5.86
   033070JR     454.00     905.00      9.00   11500.00       0.42      0.10      0.97      0.53       0.22      8.32
   040770JR     462.00    1115.00     10.00   12600.00       0.39      0.20      0.59      0.32       0.17      0.0 B
   041270JR     467.00    1150.00     13.50    6980.00       0.16      0.14      0.28      0.52       0.10      0.0 B
   042070JR     475.00    1100.00     15.00    6810.00       0.23      0.09      0.25      0.57       0.06      0.0 B
   042870JR     483.00    1540.00     17.50    9700.00       0.14      0.14      0.17      0.62       0.03      5.42
   050670JR     491.00    1015.00      0.0 B   9510.00       0.23      0.12      0.39      0.57       0.08      0.0 B
   051170JR     496.00     915.00     21.50    4980.00       0.13      0.12      0.36      0.65       0.02      4.26
   051870JR     503.00    1140.00     21.00    4450.00       0.13      0.10      0.29      0.59       0.02      5.00
   052570JR     510.00     940.00     27.00    2450.00       0.16      0.12      0.23      0.58       0.03      3.53
   060270JR     518.00    1125.00     25.00    1740.00       0.12      0.11      0.91      0.83       0.10      0.0 B
   060970JR     525.00    1110.00     27.00    1490.00       0.13      0.11      0.70      0.14       0.0 T     0.0 B
   061673JR     532.00    1040.00     25.50    1190.00       0.08      0.05      0.61      0.88       0.10      4.89
   062370JR     539.00    1100.00     29.00     790.00       0.11      0.04      0.49      0.84       0.10      4.82
   063070JR     546.00    1510.00     27.00     380.00       0.10      0.07      0.65      0.41       0.02      2.89
   070670JR     552.00    1045.00     29.00     990.00       0.08      0.06      0.78      0.64       0.06      3.76
   071370JR     559.00    1100.00     28.00    2090.00       0.08      0.08      0.55      0.91       0.06      5.37
   072170JR     567.00    1100.00     28.00     510.00       0.15      0.09      0.81      0.0 T      0.02      4.75
   072770JR     573.00    1115.00     29.00    1190.00       0.16      0.07      0.68      1.05       0.08      6.57
   080470JR     581.00    1125.00     30.00    1510.00       0.17      0.17      0.66      1.26       0.06      7.79
   081170JR     588.00    1230.00     22.50    1690.00       0.15      0.14      1.48      1.26       0.04     12.89
   061869CH     170.00      0.0 B     21.00     215.00       0.82      0.63      0.50      0.12       0.08     12.68
   062569CH     176.00    1325.00     25.00     254.00       0.97      0.76      1.18      0.28       0.11     17.64
   063069CH     181.00    1245.00     26.50      32.00       1.00      1.00      1.38      0.49       0.0 T    14.21
   070769CH     188.00    1330.00     26.50      39.00       1.26      1.26      0.62      0.0 B      0.0 B    12.13
   071669CH     197.00    1020.00     24.00      36.00       0.93      0.84      0.85      0.36       0.04     11.40
   072369CH     204.00    1240.00     24.00     139.00       0.26      0.16      0.56      0.07       0.07      0.0 B
   073169CH     212.00    1000.00     23.00     780.00       0.60      0.38      0.86      0.12       0.10     16.58
   080769CH     219.00    1030.00     22.00    1620.00       0.50      0.36      0.82      0.09       0.04     17.03
   081469CH     226.00     945.00     22.00     456.00       0.65      0.44      0.97      0.15       0.02     17.02
   082869CH     240.00    1110.00     19.00     520.00       0.69      0.55      0.91      0.13       0.08      0.0 B
   090469CH     247.00    1100.00     23.00      83.00       0.67      0.45      0.82      0.40       0.07      0.0 B
   091169CH     254.00    1155.00     20.00     116.00       0.70      0.60      0.71      0.42       0.08      0.0 B
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10

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D0034 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                DATE  12/17/71

                                              CHESAPEAKE BAY NUTRIENT INPUT

 SAMPLE        J DATE      TIME        TEMP      FLOW        TPO4        PI         TKN      NO2&NO3      NH3        TOC

072269PJ       203.00     945.00      23.00     282.00       2.60       2.12       1.83       0.69       1.44      12.63
073069PJ       211.00     940.00      22.50     660.00       1.22       0.73       1.47       0.63       0.59       0.0 B
080669PJ       218.00     945.00      20.00     280.00       1.73       1.62       1.38       1.13       0.62       0.0 B
081369PJ       225.00     930.00      20.00     240.00       1.25       1.00       1.35       0.89       0.73       9.37
082069PJ       232.00     940.00      21.00     450.00       1.58       1.51       0.0 B      0.84       0.88       8.57
082769PJ       239.00     945.00      19.00     130.00       2.61       2.57       1.48       2.34       0.71       6.78
090369PJ       246.00     910.00      21.00     600.00       0.18       0.0 B      3.12       1.10       0.42      16.20
091069PJ       253.00     930.00      18.50     168.00       2.73       0.60       1.32       2.18       1.10       6.09
091769PJ       260.00     915.00      19.50     100.00       0.55       0.0 B      1.11       2.40       1.11       0.0 B
092469PJ       267.00     925.00      15.00     111.00       4.63       4.63       1.44       3.00       1.12       4.51
100669PJ       279.00     950.00      14.50     113.00       5.56       2.93       1.25       2.25       0.97      24.90
102269PJ       295.00     935.00      13.00     142.00       5.73       3.00       2.30       1.56       1.51       0.0 B
111169PJ       315.00    1030.00      10.00     145.00       4.23       4.15       3.56       1.10       0.19       0.0 B
111969PJ       323.00     900.00       7.00     130.00       4.26       4.25       0.0 B      1.68       2.10       0.0 B
112469PJ       328.00     945.00       5.50     146.00       4.27       3.38       2.83       0.74       0.83       2.90
120169PJ       335.00    1000.00       4.00     139.00       4.51       4.22       3.41       1.58       2.56       0.0 B
120669PJ       343.00     945.00       4.00     307.00       3.05       1.60       1.23       0.90       1.23       0.0 B
121169PJ       345.00    1345.00       9.00    1098.00       4.21       1.44       1.42       0.80       0.49       0.0 B
121269PJ       346.00     815.00       6.00    1290.00       2.19       1.12       1.26       0.97       0.67       0.0 B
121569PJ       349.00     945.00       3.00     251.00       2.92       0.0 B      1.83       0.0 B      0.0 B      0.0 B
122969PJ       363.00     940.00       1.00     329.00       2.26       1.31       1.00       1.00       1.00       0.0 B
010570PJ       370.00     950.00       0.0      216.00       2.26       1.60       2.30       1.24       1.75       1.64
011970PJ       384.00    1415.00       0.50     698.00       1.96       0.80       2.36       0.67       0.85       5.60
012570PJ       390.00     925.00       1.00     217.00       3.13       2.22       2.98       1.29       1.90       2.00
020270PJ       398.00       0.0 B      5.00     220.00       2.01       1.89       2.15       1.17       1.65       1.90
020370PJ       399.00    1045.00       5.00     552.00       2.56       1.54       1.88       1.05       1.05       7.31
020470PJ       400.00    1000.00       0.0      860.00       0.0 B      0.44       1.67       1.00       0.75      11.45
020970PJ       405.00     905.00       3.00     243.00       3.33       2.09       2.37       1.10       2.04       3.10
021170PJ       407.00       0.0 B      3.00    1910.00       1.42       0.76       1.67       0.88       0.42       0.0 B
021270PJ       408.00     915.00       3.00     588.00       1.57       0.67       0.0 B      0.96       0.70       2.12
021670PJ       412.00    1030.00       1.00     375.00       1.41       1.15       1.21       0.95       1.01       0.0 B
022470PJ       420.00     915.00       0.0 B    287.00       1.94       1.34       1.23       0.77       0.92       4.05
030370PJ       427.00     920.00       1.00     211.00       2.66       2.19       2.12       1.09       2.12       4.20
030970PJ       433.00    1230.00       6.00     230.00       1.98       1.79       2.02       1.03       2.02       4.73
031670PJ       440.00    1040.00       4.00     205.00       3.30       2.30       3.65       1.04       3.65       5.37
032370PJ       447.00    1010.00       5.00     614.00       1.15       0.66       1.42       0.85       0.98       6.03
033070PJ       454.00     905.00       4.00     761.00       2.24       0.44       1.50       0.96       0.66       9.76
040170PJ       456.00     455.00       5.00     488.00       1.44       0.97       0.94       0.81       0.74       0.0 B
040370PJ       458.00    1415.00       9.50    2231.00       2.80       0.15       0.0 B      0.55       0.56      15.18
040870PJ       463.00     745.00       7.00     477.00       2.10       1.03       1.21       0.96       1.21       0.0 B
041570PJ       470.00    1435.00       8.50    2476.00       1.02       0.58       1.06       0.68       0.45       0.0 B
041970PJ       474.00    1225.00      12.00     630.00       1.10       0.67       0.98       0.95       0.55       0.0 B
050670PJ       491.00    1215.00      14.00     330.00       1.93       1.62       1.31       1.18       1.08       0.0 B
051170PJ       496.00     920.00      18.50     222.00       2.49       2.36       1.26       1.55       0.63       5.43
051870PJ       503.00    1445.00      16.00     468.00       2.01       0.15       1.07       1.18       0.51      13.88
052570PJ       510.00     915.00      19.00     666.00       0.0 B      0.78       1.94       1.31       0.54      10.29
060170PJ       517.00    1355.00      19.40     186.00       3.12       2.25       1.56       2.06       0.53       5.84
060870PJ       524.00    1030.00      18.50     181.00       4.93       2.24       0.92       2.10       0.91       0.0 B
061570PJ       531.00     925.00      19.00     139.00       3.53       2.84       0.68       2.82       0.61       6.19
062270PJ       538.00    1100.00      21.00     576.00       1.51       1.23       2.95       1.48       0.59      16.87
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D0039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                         DATE   12/17/71
                                                    CHESAPEAKE BAY NUTRIENT INPUT
  SAMPLE       J DATE        TIME       TEMP       FLOW         TPO4         PI          TKN      NO2&NO3        NH3          TOC

 091869CH      261.00      1040.00      20.50       56.00        0.76        0.62        0.64        0.33        0.06         9.02
 100269CH      275.00      1125.00      16.00       90.00        0.62        0.43        0.50        0.34        0.05         0.0 B
 100969CH      282.00      1125.00      19.00      130.00        0.48        0.36        0.07        0.0 B       0.0 B        0.0 B
 102269CH      295.00      1040.00      15.50       44.00        0.83        0.42        0.87        0.18        0.08         0.0 B
 111269CH      316.00       955.00       9.50       99.00        0.70        0.40        0.66        0.05        0.0 T       14.40
 111769CH      321.00      1200.00       7.00       96.00        0.44        0.22        0.97        1.02        0.06         0.0 B
 111869CH      322.00      1155.00       7.00       90.00        0.62        0.40        0.83        0.10        0.03         0.0 B
 112469CH      328.00      1240.00       6.00      165.00        0.46        0.35        0.63        0.03        0.02         5.80
 120269CH      336.00      1145.00       3.00       80.00        0.58        0.50        1.72        0.23        0.08         0.0 B
 121169CH      345.00      1240.00       8.00      180.00        0.55        0.38        0.40        0.10        0.04         0.0 B
 121569CH      349.00      1200.00       5.00      300.00        0.37        0.0 B       0.59        0.0 B       0.0 B        0.0 B
 122969CH      363.00      1255.00       2.00      480.00        0.25        0.20        0.42        0.24        0.03         0.0 B
 010570CH      370.00      1215.00       0.0       310.00        0.27        0.24        0.43        0.21        0.05         7.89
 011970CH      385.00      1140.00       1.00      293.00        0.27        0.21        0.42        0.35        0.11         2.40
 012670CH      392.00      1145.00       1.00      254.00        0.26        0.20        0.42        0.33        0.22         3.70
 020270CH      398.00      1100.00       5.00      240.00        0.24        0.23        0.88        0.16        0.27         7.61
 020470CH      400.00      1145.00       3.00      293.00        0.29        0.26        0.27        0.16        0.04         6.85
 020970CH      405.00      1135.00       4.50      377.00        0.24        0.19        0.46        0.20        0.18        13.30
 021270CH      408.00      1245.00       5.50      391.00        0.22        0.20        0.95        0.20        0.12         5.28
 021670CH      413.00      1145.00       6.00      478.00        0.17        0.14        1.22        0.12        0.04         0.0 B
 022470CH      420.00      1145.00       5.50      412.00        0.27        0.19        0.67        0.09        0.04         8.80
 030270CH      426.00      1155.00       6.00      229.00        0.34        0.22        0.37        0.27        0.04         6.60
 030970CH      433.00      1235.00       8.00      235.00        0.32        0.16        2.04        0.20        0.07         8.22
 031670CH      440.00      1100.00       5.50      188.00        0.40        0.27        0.39        0.22        0.04         8.11
 032370CH      447.00      1135.00       8.00      394.00        0.23        0.17        0.53        0.18        0.06         8.58
 033070CH      454.00       945.00       8.00      483.00        0.27        0.17        0.58        0.14        0.16         8.74
 040769CH      462.00      1200.00       9.50      675.00        0.0 B       0.39        0.96        0.05        0.10         0.0 B
 041270CH      467.00      1225.00      14.00      337.00        0.17        0.17        0.27        0.0 T       0.10         0.0 B
 042070CH      475.00      1145.00      15.50      333.00        0.35        0.17        0.67        0.0 T       0.03         0.0 B
 042870CH      483.00      1445.00      17.00      332.00        0.43        0.30        0.36        0.09        0.03        12.50
 050670CH      491.00      1050.00       0.0 B     302.00        0.60        0.44        0.80        0.33        0.19         0.0 B
 051170CH      496.00       955.00      21.00      217.00        0.68        0.31        0.79        0.19        0.04        16.63
 051870CH      503.00      1240.00      17.00      115.00        0.74        0.41        0.73        0.44        0.08        13.98
 052570CH      510.00      1020.00       0.0 B      61.00        0.74        0.52        0.92        0.53        0.07        10.71
 060270CH      518.00      1215.00      22.50       71.00        0.69        0.53        1.37        0.48        0.07         0.0 B
 060970CH      525.00      1210.00      23.00       38.00        0.76        0.65        0.56        0.46        0.0 T        0.0 B
 061670CH      532.00      1125.00      21.00       24.00        0.63        0.11        0.70        0.29        0.10         8.67
 062370CH      539.00      1150.00      26.00       27.00        0.60        0.45        0.58        0.18        0.10         7.61
 062970CH      545.00      1610.00      23.50       26.00        0.91        0.11        0.86        0.29        0.02         6.38
 070670CH      552.00      1135.00      24.00       86.00        0.62        0.39        0.68        0.18        0.03         8.24
 071370CH      559.00      1150.00      24.00       61.00        0.55        0.43        0.65        0.11        0.08        10.66
 072170CH      567.00      1155.00      23.00       28.00        1.04        0.73        0.83        0.40        0.03         7.81
 072770CH      573.00      1210.00      26.00      126.00        0.63        0.49        0.57        0.17        0.08        10.69
 080470CH      581.00      1230.00      27.00       17.00        1.25        0.17        1.13        0.46        0.06        16.31
 081170CH      588.00      1140.00      23.00       10.00        1.13        0.98        0.54        0.43        0.04        15.64
 061669PJ      167.00         0.0 B     20.00      213.00        2.50        2.50        2.59        1.60        1.69         0.0 B
 062369PJ      174.00       955.00      24.50      117.00        3.56        3.30        0.98        2.21        0.98         8.58
 070269PJ      183.00      1305.00      28.50       86.00        5.38        5.10        1.29        2.72        0.78         4.76
 070969PJ      190.00      1125.00      20.00       93.00        4.97        1.99        0.73        2.24        0.73         6.80
 071569PJ      196.00       945.00      22.50       97.00        3.32        0.0 B       1.11        2.10        0.81         6.56
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00039 PUBLICATION LISTING - USGS STATPAC (11/19/71)                                                      DATE  12/17/71

                                                  CHESAPEAKE BAY NUTRIENT INPUT

 SAMPLE       J DATE       TIME        TEMP      FLOW        TPO4        PI          TKN      NO2&NO3        NH3        TOC

070670PJ      552.00      850.00       21.50     300.00       3.30       2.38        1.59       1.65         0.48       6.06
071570PJ      561.00     1400.00       23.00     179.00       2.89       2.40        1.35       1.52         0.76       5.46
072770PJ      573.00     1145.00       24.00     163.00       2.44       2.26        1.60       1.93         0.49       8.63
080470PJ      581.00      920.00       23.00     116.00       2.86       2.75        1.29       1.80         0.49       9.33
081170PJ      588.00      925.00       22.00     112.00       6.30       3.25        1.02       2.00         0.32      10.28
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